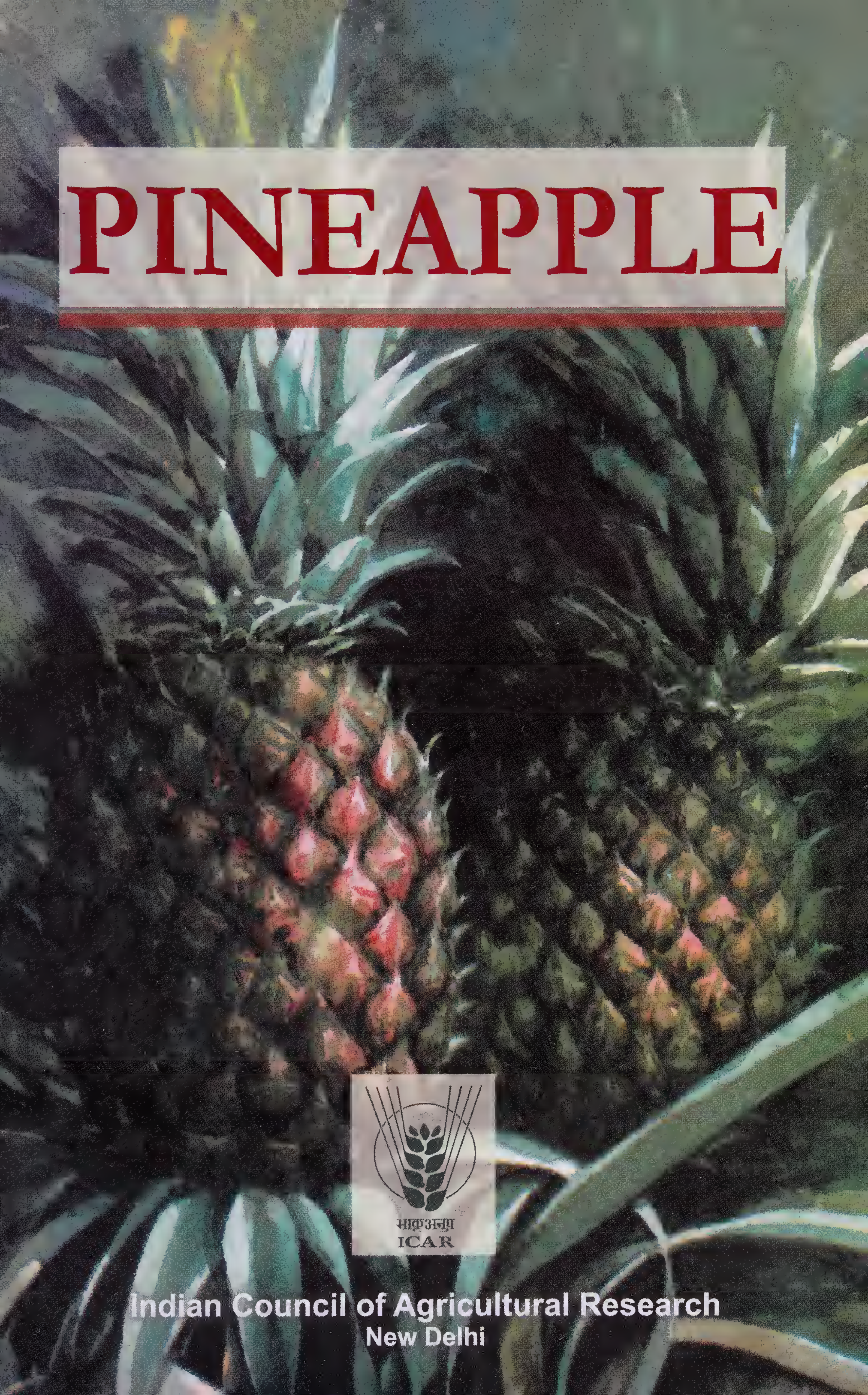
PINEAPPLE



भाकृअनुप
ICAR

Indian Council of Agricultural Research
New Delhi

Pineapple

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Preface

Pineapple has all the qualities required for being an ideal fruit-crop. It is highly nutritious with exquisite flavour, well suited for processing into various products. It is a potential dollar earner, with great demand both in fresh and processed forms in the International Market.

According to the Indian Institute of Foreign Trade, high cost of pineapple production is one among the few causes limiting its export from India. Lack of scientific production technology is the prime reason for its low productivity and high cost of production. Being a hardy plant, pineapple is grown with least care in humid regions of the country. Wider spacing, continued ratooning, inadequate manuring and other crop-husbandry practices contribute to its poor yields.

Research work to evolve a scientific package of cultural practices aimed at increasing productivity and reducing cost of production was initiated during late sixties. Multilocational trials encompassing inter-disciplinary and inter-institutional approach were carried out under the All-India Co-ordinated Fruit Improvement Project of the ICAR at the Indian Institute of Horticultural Research, Bangalore and its regional stations at Chethalli (Malnad Region), Kerala Agricultural University and Assam Agricultural University, in addition to the research carried out by the Bidhan Chandra Krishi Vishwa Vidyalaya, West Bengal, and other state agricultural universities.

Efforts have been made in this bulletin on *Pineapple* to analyse problems of its production and to consolidate research information contained in about 250 references into 18 chapters, covering all aspects of pineapple production in a simple, straight and comprehensive form. It is hoped that the information provided in this will be quite useful for farmers, extension personnel, researchers, students, teachers and all concerned with pineapple alike.

The help, support and suggestions by our colleagues at the Indian Institute of Horticultural Research, Bangalore, and at the ICAR, New Delhi, are duly acknowledged. We are grateful to the ICAR for bringing out this publication.

— K.L. Chadha, B.M.C. Reddy, S.D. Shikhamany

CONTENTS

1
Introduction

PINEAPPLE (*Ananas comosus* (Linn.) Merr.), known as *ananas* in Hindi, is one of the commercially important fruit-crops of India. The modern pineapple is a cultigen which was domesticated in pre-columbian times in South America. Existence of pineapple was not known to people of old world before Columbus made his voyage to the new world. On 3 November 1493, Columbus and his crew recorded pineapple in a West Indies village in an Island of Lesser Antilles.

Its pleasant flavour and exquisite taste qualifies pineapple as one of the choicest fruits throughout the world. Pigafetta (1519) reported presence of pineapple in Brazil and described it as an exquisite fruit in existence. In his book "Historia Generall y Natural de La Indias", Oviedo (1535) stated that "there are no other fruits in the whole world to equal them for their beauty of appearance, delicate fragrance and excellent flavour".

The name pineapple is derived from Spanish name 'Pina', given to the plant, based on the appearance of its fruits, which resemble a pine cone. The name 'Ananas', which later became the generic name, is derived from Tupi Indian name 'Nana'.

Pineapple is a good source of carotene (vitamin A) and ascorbic acid (vitamin C) and is fairly rich in vitamins B and B_2 (Lal and Pruthi, 1955). It also contains phosphorus and minerals like calcium, magnesium, potassium and iron (Lodh *et al.*, 1972). Besides, it is also a source of bromelin, a digestive enzyme (Lodh *et al.*, 1973). It provides adequate roughage to prevent constipation. Its fresh juice has a cooling and refreshing effect, especially in summer. As an appetizer, the juice can be given safely to patients suffering from liver diseases, nephritis, stomach complaints, heart diseases and general weakness. A piece of 100 g pineapple-flesh contains 87.0 g water, 0.6 g protein, 0.1 g fat, 12.3 g carbohydrates, 12 mg calcium, 10 mg phosphorus, 0.4 mg iron, 250 mg potassium, 1.5 mg sodium, 0.08 mg copper, 17 mg magnesium, 50 IU of carotene, 0.02 mg vitamin B_1, 0.12 mg vitamin B_2, 4 mg folic acid, 50 mg ascorbic acid, and gives 50 calories of energy.

The fruit, in addition to being eaten fresh, can also be canned and processed in different forms. Pineapple-bran, a dried rag of pulp after pressing for juice, is a good cattle feed. A very fine fibre is extracted from its leaves for making a light but stiff fabric (Hayes, 1960), called pina-cloth.

2

Origin and Distribution

ORIGIN

THE geographical distribution of the existing wild species leads to the supposition that the area of pineapple origin is the region bound by 15°–30° south latitude and 40°–60° west longitude. Bertoni (1919) considered Paraguay as the place of origin of *Ananas comosus*. The cultivated seedless-pineapple is the result of a natural mutation in the wild seeded-pineapple. The name of the genus, *Ananas*, is derived from the Tupi-Guarani Indian word 'Nana'; in whose country pineapple has apparently originated. It has been suggested that the Tupi-Guarani Indians first selected and cultivated *A. comosus* at its centre of origin, and later took it with them on their subsequent migrations. Baker and Collins (1939) believed the place of origin to be somewhere in the region including central and southern Brazil, northern Argentina and Paraguay; as the maximum genetic diversity of pineapple is found in this region. They recorded 2 forms of wild *A. comosus*. The wild plants growing in Matto Grosso, Moura Brazil and Rio de Janeiro were more vigorous and fruits were smaller and more palatable than the wild plants growing in other places of Brazil and Trinidad Islands. The modern pineapple is a cultivar which was domesticated in Pre-Columbian times in South America. A mutation for seedlessness occurred and selections were made for bigger fruit size, juiciness, sweetness and improved flavour. Collins (1960) considered that the centre of origin was probably in the drainage area of the Panama-Paraguay river, where related seedy species *Ananas bracteatus*, *A. ananassoides*, *A. erectifolius* and *Pseudananas sagenarious* occurred wild and some of these were also cultivated for fibre. The wild species of seeded-pineapple are still seen growing naturally in tropical America, and the cultivation of pineapple in Brazil must have been many centuries old (Laufer, 1929). The belief that long continued propagation of a domesticated species by slips and suckers would somehow must have resulted in plants which lost their ability to produce seeds, has become rather generally accepted, and Brazil is recognized as the centre of origin of the present-day cultivated pineapples.

DISTRIBUTION

Tupi-Guarani Indian tribes are believed to have migrated northwards and westwards taking pineapple along with them and

introducing it to other tribes in the new areas. By the dual process of tribal migration and border trading between tribes, the first varieties of pineapple got distributed throughout the tropical America, and the species developed into a cultivar in the process.

Later, pineapples incited interest and enthusiasm of the early explorers and settlers of America more than any other plant. When these voyagers started going from America to other lands, many of them carried pineapple-fruits, and sometimes even the entire plant. The pineapple-plants, suckers, slips and crowns withstand considerable desiccation and resume growth when planted; thereby, making pineapples easy to establish in new areas. After the discovery of the New World, pineapples spread was very rapid throughout the tropics. They were either introduced into or were reported to be growing in the Old World (St Helena, 1505; Madagascar, 1548; southern India, 1550; Philippines, 1558; Java, 1599; West Africa, 1602; Formosa, 1650; South Africa, 1660; Mauritius, 1661; Australia, 1839). Pineapple was introduced into Hawaii in the early nineteenth century.

Pineapples are now widely grown throughout the tropics and subtropics. Their development as an important economic fruit-crop in Malaya, Hawaii, Australia, Ceylon, Formosa, India, Java, Philippines, Singapore, South Africa, Sumatra and elsewhere has occurred during the present century. The region between latitudes 25° north and 25° south of the equator is regarded as specially favourable for growing pineapples, though cultivation of this tropical fruit has also been successful beyond these limits, as is proved by the extensive cultivation in South Africa and Australia.

3
Area and Production

WORLD SCENARIO

PRODUCTION of fresh pineapple in the World has shown an increase from 9.7 million tonnes in 1990 to 11.5 million tonnes in 1995 (Table 1). However, Asia has remained the major pineapple-producing region, contributing 57.89% to the World production; followed by Africa with a share of 16.5%, South America with 14.32%, North and Central America with 10.21% and Australia with a meagre 1.29%. Surprisingly, the share of pineapple production in Asia has not changed much during the last 6 years, being 58.44% in 1990 and 57.89% in 1995.

Thailand, Philippines, Brazil, India, Nigeria, China, Indonesia,

Table 1. Production of pineapple in different continents

(Production in thousand tonnes)

	1990	1991	1992	1993	1994	1995
Asia	5,681	5,942	6,299	6,735	6,635	6,632
Africa	1,205	1,242	1,253	1,919	1,864	1,905
America	1,223	1,284	1,379	1,562	1,715	1,654
North and Central America	1,441	1,436	1,384	1,142	1,220	1,179
Australia	142	142	145	143	157	150
Europe	2	2	2	2	2	2
Estimated total production	9,720	10,076	10,490	11,527	11,617	11,547

Source : FAO Production Yearbook 1992 & 1995

Table 2. Production of pineapple in major producing countries of the world

(Production in thousand tonnes)

	1990	1991	1992	1993	1994	1995
Thailand	1,865	1,876	1,900	2,589	2,370	2,370
Philippines	1,156	1,160	1,170	1,287	1,324	1,360
Brazil	724	787	800	835	974	913
India	602	700	820	859	820	820
	(6.19)	(6.94)	(7.81)	(8.18)	(7.05)	(7.10)
Nigeria				800	800	800
China	785	927	1,000	777	852	792

Figures in parentheses indicate percentage share in World production.
Source : FAO Production Yearbook 1992 & 1995

Columbia, the USA and Vietnam are the 10 pineapple-producing countries in the World in order of their production. India has emerged as the fourth largest pineapple-producing country of the World. However, its share of World production, which was 6.19% in 1990, has marginally increased to 7.10% in 1995 (Table 2).

INDIAN SITUATION

Even though climate prevailing in the large parts of our country is ideal for pineapple cultivation, still this fruit-crop does not hold any

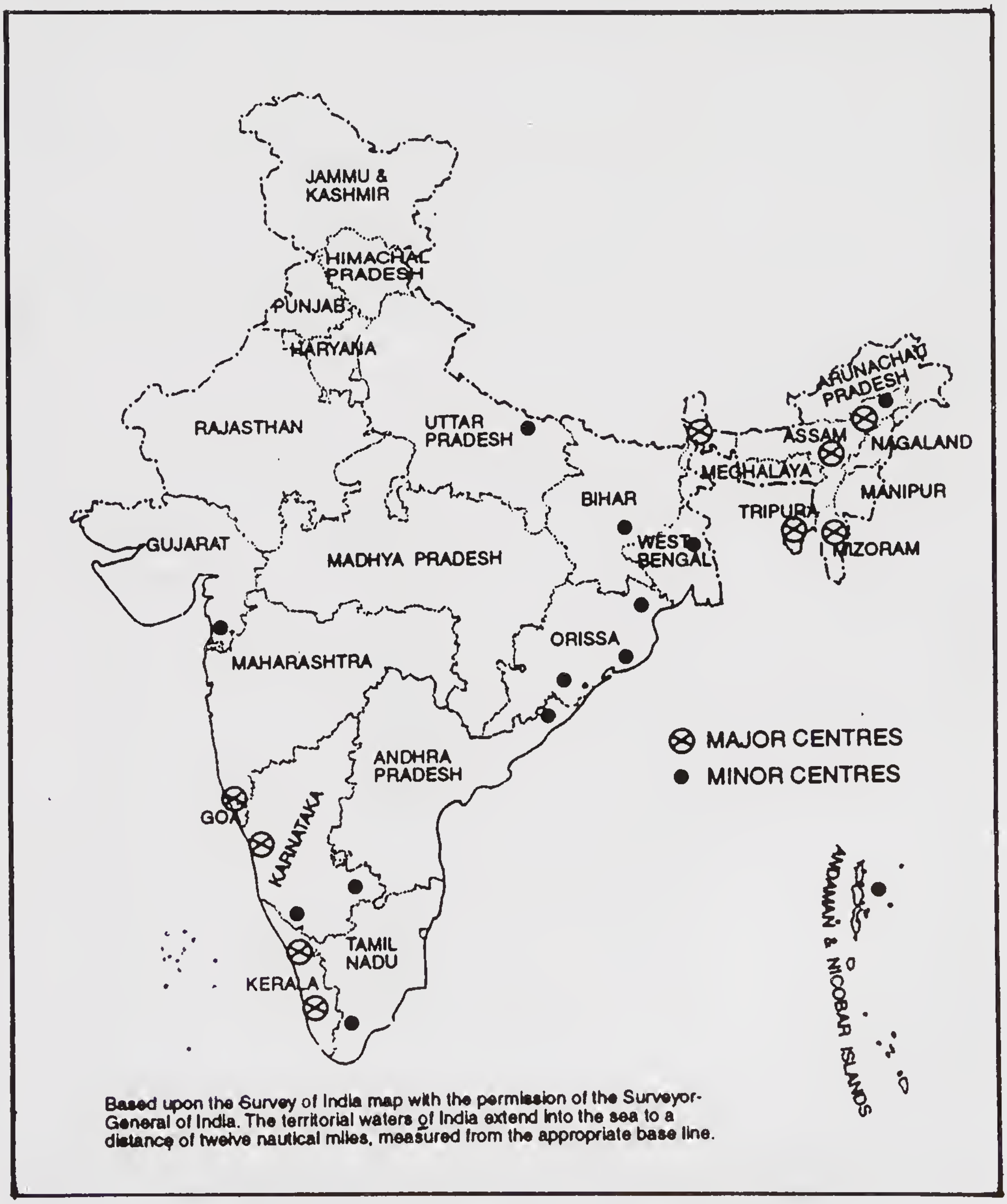

Fig. 1. Centres of pineapple cultivation in India

position of importance among the major fruits being cultivated in the country. Commercial cultivation of pineapple started only 3 or 4 decades ago, especially on the West Coast. Pineapple is grown in Assam, Meghalaya, Tripura, Mizoram, West Bengal, Kerala, Karnataka and Goa on a large scale, and in Gujarat, Maharashtra, Tamil Nadu, Andhra Pradesh, Orissa, Bihar and Uttar Pradesh on a small scale (Fig. 1).

In 1946, the area under this fruit was estimated at about 4,000 hectares. Even in 1957, the area remained the same. It was, however, reported to have been doubled by 1961-62, when the Directorate of Marketing and Inspection placed area under pineapple at 7,830 hectares and production at 75,650 tonnes. The area and production during 1976-77 were 40.72 thousand hectares and 671.82 thousand tonnes, with a productivity of 10.88 tonnes/ha (Subrahmanyam, 1989). During the last thirteen years, from 1979-80 to 1992-93, the increase in area, production and productivity of pineapple was 34.06%, 77.63% and 32.44%.

Area under pineapple was highest in Assam, followed by West Bengal, Mizoram and Meghalaya; and the production was high in Assam, followed by Karnataka, Meghalaya, Manipur, Bihar and Kerala. The productivity was maximum in Tamil Nadu, followed by Bihar and Karnataka (Table 3).

Table 3. Statewise area and production of pineapple in 1992–93

State	Area (ha)	Production (tonnes)	Productivity (tonnes/ha)
Andhra Pradesh	3,686	13,690	3.71
Assam	13,906	184,485	13.30
Bihar	2,705	67,625	25.00
Goa	460	6,700	14.50
Karnataka	3,082	107,562	34.90
Kerala	5,000	47,000	9.40
Manipur	6,450	60,500	9.38
Meghalaya	8,450	72,500	8.58
Mizoram	810	4,189	5.17
Nagaland	1,017	2,415	2.37
Orissa	561	9,000	16.00
Tamil Nadu	702	28,782	41.00
Tripura	3,706	32,000	8.63
West Bengal	8,90C	222,500	25.00
Pondicherry	1	30	30.00
Total	59,436	858,978	14.45

Source : Department of Agriculture and Co-operation. 1995. Horticultural statistics (compiled by the National Horticultural Board), Ministry of Agriculture, Government of India

For increasing pineapple production, it is necessary to increase productivity rather than area under this crop. But most of the pineapple growers are not following scientific techniques and are not giving any fertilizers, irrigation and plant-protection measures to this crop. Steps need to be taken to educate cultivators to follow scientific methods.

4

Botany — Morphology and Taxonomy

MORPHOLOGY

PINEAPPLE is a herbaceous, perennial, self-sterile, monocotyledonous plant of about 90-100 cm in height, with spreading leaves, which give the plant a rosette appearance. The plant bears a single fruit terminally on a peduncle, protruding out from the centre of the rosette. Growth continues after fruiting by one or more axillary buds from the leaf axils, which grow into vegetative branches and come to maturity while still attached to parent plant. The crop from the plant growing from a separated vegetative shoot is commonly called as a plant crop and that from the plant produced from axillary branch is a ratoon crop. In this way plant may continue growing and fruiting for over fifty years. In commercial production, however, only 1 or 2 ratoon crops are taken, after which plants are uprooted and replanted.

Normal fruiting pineapple-plant consists of suckers, slips, peduncle and crown in addition to leaves, stem and roots (Fig. 2).

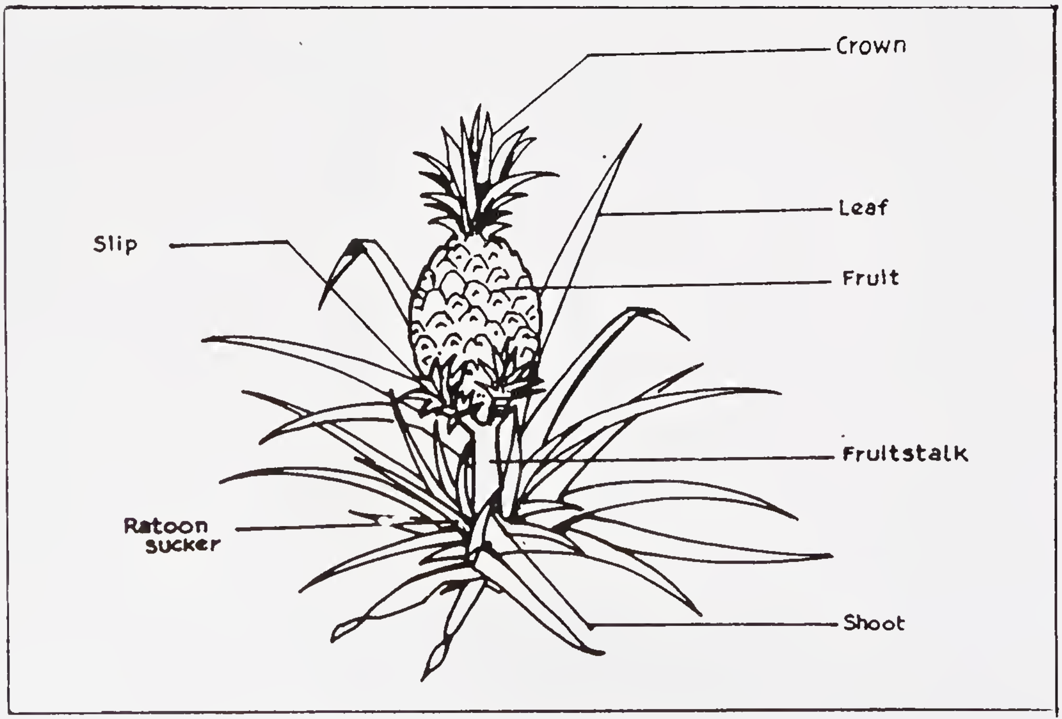

Fig. 2. Various parts of a pineapple-plant

Depending on the point of origin, the suckers are called ground-suckers if they arise from buds of the underground portion of the stem or shoots, and slips if they arise from axillary buds of the aerial portion of the stem. Slips are leafy branches, attached below the fruit, and are developed from the axillary buds on the peduncle. Peduncle is a slender, leaf-bearing stalk, supporting fruit and connecting it with stem. Crown is the miniature plant, consisting of condensed stem and leaves, growing from the apex of the fruit.

Root system is adventitious, dense and shallow, and is concentrated mainly in the upper 15 cm of the soil, and rarely extends to a depth of 30 cm. Roots are differentiated into soil-roots, growing from the underground portion of the stem, and axillary-roots, which do not enter soil, and remain tightly wound around stem at the leaf axils, and are often flattened. They originate near the central cylinder or stele and push downwards and outwards through cortex, emerging from epidermis, usually from the internodes.

The stem is short and thick, 15-25 cm long, narrow at the base and wider at the top with short internodes. The base is curved in slips, but is straight in other propagules. When fruit is developing, axillary buds in leaf axils elongate to form lateral branches called shoots. Rarely buds at the base of the peduncle grow-out to produce hapas. The basic difference between hapas and suckers is that hapas develop higher up the stem, in transition zone between the stem and peduncle.

The leaves are long and narrow, and are arranged in a right-or-left-handed spiral on a short stem, forming a rosette. The number of functional leaves ranges from 35 to 60, and there is a bud in every leaf axil. The leaves either have smooth edges with a few spines just below the tip, or have spines all along the margins. The tip is elongated, ending in a finer point. Leaves are sessile with clasping base, excepting near apex; lamina is shaped like a shallow trough which conducts water to the base of the plant. The upper leaf surface is green and the lower is silvery-white, due to the presence of trichomes. Trichomes are multicellular hairs with short stalks, arranged in furrows; the flattened tops of the air-filled dead cells spread out and cover ridges and give leaf undersurface a white appearance. The trichomes on the clasping leaf-bases absorb water and nutrients (in solution), but on the rest of the leaves they probably insulate leaf and protect stomata, which are borne only on the undersurface.

Leaf anatomy shows water-storing tissue and air canals. All these features contribute to the ability of the pineapple to withstand drought.

The number of stomata reported were 180 per mm^2 in Cayenne and less for triploid and tetraploid hybrids (132 and 105) by Collins (1960);

Py and Tisseau (1965) reported the number as 70–80 and Purseglove (1972) in the range of 70–85. This number is much lower than banana (220/mm^2), citrus (500/mm^2) and other crops. This may be linked with the type of photosynthesis which takes place in pineapple. In this plant, stomata remain closed during the day, thereby reducing moisture loss. Because of this an ordinary system of photosynthesis does not work, and the plants use CAM system (Crassulacean acid metabolism), in which CO_2 is reduced to organic acids (mainly citric and malic), which accumulate in leaves at night and are reduced to sugars during day.

Inflorescence and Flowers

Apical meristem broadens to form a compact inflorescence about 10-15 months after planting, although this period varies according to cultivar and type of planting material used. Plant bears a total of 100-200 reddish-purple flowers, arranged spirally on the axis, each subtended by a floral bract. Each flower has 2 perianth whorls, an outer one of 3 short, free calyx segments and an inner one of 3 larger petals, which are also free, though they form a tube enclosing 6 stamens and a narrow style with its 3-lobed stigma. The inferior ovary has 3 united carpels with 10-15 ovules in each of the 3 loculi. Flowers open in early morning at a rate of 5-10 per day, from the base of the inflorescence upwards over a period of 10-20 days. They are normally self-sterile and fruit development is parthenocarpic. Cross-pollination between varieties results in normal fertilization and production of seeds.

Fruit

The fruit is a syncarp or multiple fruit, formed by the fusion of fruitlets, produced by each flower. The multiple fruit matures in 5-6 months after flowering. It is formed by an extensive thickening of the axis of the inflorescence and by the fusion of the small, berry-like fruitlets, produced by each flower (Fig. 3). The sepals and the pointed floral bract, subtending each flower, persist and form hard rind of the fruitlets, and become more or less fused in the process with the adjacent flowers. There are 100-200 individual fruitlets arranged spirally around the thick central axis and the whorl forms a broad, almost cylindrical fruit. Growth through cell division is complete during flowering, and increase in fruit size during development is by enlargement of cells. The fruit tapers towards top and bears crown. Growth of the crown continues during fruit development, but ceases when fruit matures.

Seeds

Cultivars are seedless when grown on pure stand. When natural or

cross-pollination occurs between cultivars and species, 2,000-3,000 very hard seeds may be produced.

TAXONOMY

Pineapple belongs to the family Bromeliaceae; a large family of American tropics. Most of the bromeliads are epiphytes (they live on trees) but pineapple is terrestrial.

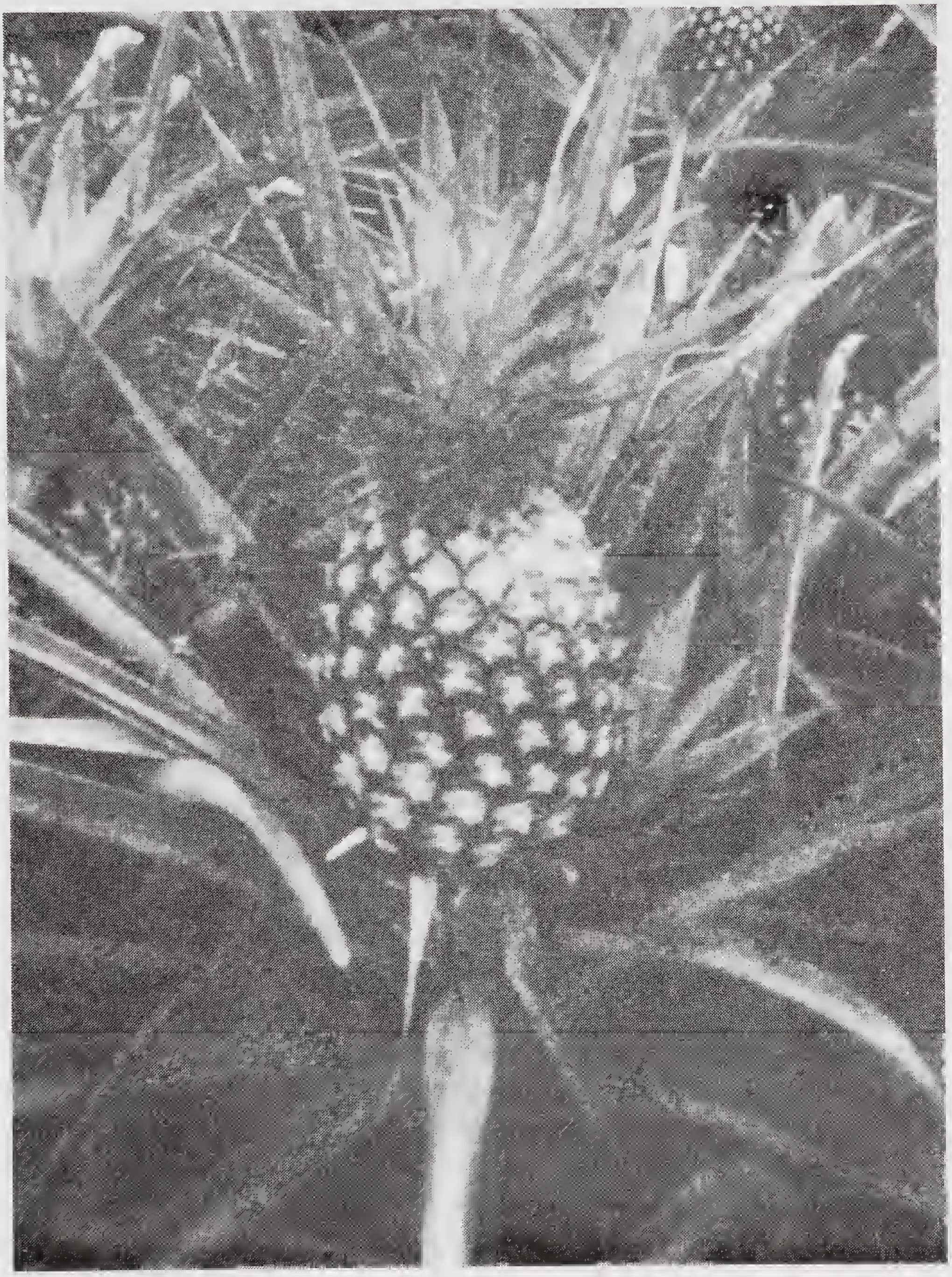

Fig. 3. Ideal shape of Kew pineapple-fruit

Many a members of the family in nature are found in tropical and sub-tropical regions of America. *Ananas* and the closely related monotypic genus *Pseudananas* are distinguished from other genera of Bromeliaceae by their syncarpous fruits which, in *Ananas*, bear a terminal crown of reduced leaves. But *Pseudananas* has no such crown. Both genera have the basic chromosome number n = 25, which is common throughout the family, but *Ananas* is typically diploid (2n = 50) while *Pseudananas* is tetraploid with 100 chromosomes and could be the result of natural hybridization between a species of *Bromelia* with 50 chromosomes and a species of *Ananas*, followed by chromosome doubling (Collins, 1960). There are 5 species in *Ananas* – *A. bracteatus, A. fruitzmuelleri, A. comosus, A. erectifolius* and *A. ananassoides* and one species in *Pseudananas, P. sagenarious.*

Both *A. bracteatus* and *A. fruitzmuelleri* produce fleshy, edible (though seedy) fruits; *A. bracteatus* had in fact been cultivated in the Parana river area (Collins, 1960). Fruits of *A. ananassoides* and *A. erectifolius* become nearly dry at maturity with little flesh. *Ananas erectifolius,* which has long, almost spineless leaves, has been considered a potential fibre-crop. Of the 900 species in the family Bromeliaceae, only the cultivated pineapple belonging to the species *A. comosus* (Linn.) Merr. is of prime economic importance.

The brief account of pineapple taxonomy is introduced here with a classification showing pineapple lineage.

Kingdom	Vegetable or plant
Sub-kingdom	Spermatophyta
Class	Angiospermae
Sub-class	Monocotyledons
Order	Farinosae
Family	Bromeliaceae
Genera	*Ananas* and *Pseudananas*

Botanical Key to the Genera and Species (Smith, 1939)

1. Syncarp bearing at maturity a minute, inconspicuous coma of reduced squamiform bract, never producing slips at its base; plant producing elongate stolons at base; petals bearing appendages in the form of lateral folds....... *Pseudananas sagenarious*
1. Syncarp bearing at maturity a conspicuous coma of foliaceous bracts, frequently producing slips at its base; plant not producing stolons; petals bearing 2 infundibuliform scales each .... *Ananas*
   2. Syncarp well over 15 cm long at maturity, with copious palatable flesh, scape stout and usually short
      3. Leaf spines at ascending; floral bracts coloured at maturity;

petals bearing scales .... *A. bracteatus*

3. Leaf spines recurved towards the base; floral bracts pale-green at maturity; petals bearing vertical folds .... *A. fruitz-muelleri*
3. Floral bracts relatively inconspicuous and soon exposing the tops of the ovaries, weakly serrulate or entire; seeds lacking or very rare ..... *A. comosus*

2. Syncarp 15 cm long or usually much shorter, with scant, unpalatable flesh at maturity; scape elongate or slender
   4. Leaves stiffly, erect, entire, except for a long terminal spine, 35 mm wide..........*A. erectifolius*
   4. Leaves recurving, serrate, not over 25 mm wide ....*A. ananassoides*

5

Varieties

ALL species of pineapples have some varieties, with the exception of *Ananas erectifolius*. The varieties of *A. comosus* (Linn.) Merr. are of particular interest because of their large number, wide distribution and edible fruits. In this chapter, the discussion of varieties is confined to only those few forms of *A. comosus* which are cultivated extensively for their fruits. The horticultural classification of pineapple varieties of Hume and Miller (1904) is currently followed. They divided cultivated varieties of pineapple into 3 main groups— (*i*) Cayenne, (*ii*) Queen and (*iii*) Spanish. The first is by far the most important group. Most of the varieties in India may be accommodated into anyone of the 3 groups. For example, Kew or Giant Kew, synonymous with Smooth Cayenne, grown most extensively in India, represents Cayenne group, and Queen another popular variety belongs to Queen group. Recently, Py *et al.* (1987) classified cultivars grown throughout the world into 5 distinct groups (Table 4).

The varieties of Cayenne and Spanish group are dual-purpose ones whereas varieties of Queen group are grown exclusively for fresh-fruit markets, as they are not suitable for canning; owing to deep eyes.

VARIETIES OF CAYENNE GROUP

Smooth Cayenne or Cayenne.

Smooth Cayenne is extensively cultivated in Hawaii, Philippines, Australia, South Africa, Puerto Rico, Kenya, Mexico, Cuba and Formosa. It is the most popular canning variety.

The plant is stocky and robust; with tapering fleshy leaves up to 90 cm in length and about 6 cm in width. The upper surface of the leaves is dark green with brownish-red irregular mottling above (due to anthocyanin pigment in the epidermis) and silvery-grey mottling beneath with smooth straight margins, excepting near the tip and the base, where there are a few small spines. The flowers are light-purple with bright-red bracts and their number on a single spike ranges from 130 to 170. The fruit is cylindrical in shape and weighs between 2 and 3 kg; the fruitlets or eyes are typically broad and flat.

As the fruit ripens, it acquires a deep-yellow to coppery-yellow colour, which first appears at the base and progresses upwards to the shoulders. The flesh is firm, close-textured, juicy and with a pale-yellow

Table 4. Inventory of main cultivars included in each group

GROUP 1 Cayenne		GROUP 2 Spanish		GROUP 3 Queen	
– Champaka 153		– Espanola Roja	– Puerto Rico, Mexico, Cuba	– Natal Queen (many suckers)	
– Champaka 180					
– Hilo	Hawaii			– V.C. Queen	South Africa
– 53-116		– 1-56 (Hybrids)		– Ripley Queen	
– 53 -656		– 1-67 (Hybrids)	Puerto Rico	– James Queen	
– F -200		– Cabezona		– Z. Queen	
– Cayenne	– South Africa	– Pina de Cumana			
		– Selengor Green (Spineless)		– Mac Gregor	
– G 25		– Nangka (Spineless)	Malaysia	– Alexandra	Australia
– G 32-33		– Gandol (Spineless)		– Common Rough	
– Cayenne de Guinea	Guinea, West Africa	– Betek (Spineless)			
– Baronne de Rathschild (Spiny leaves)		– Masmerah (Spineless)		– Mauritius.	– Malaysia
		– Castilla	– Salvador	– Comte de Paris	– Guinea
				– Victoria	– Reunion Island
– Cayenne Gaudeloupe					
– St Dominguo Cayenne	West Indies				
– Champaka					
– Queensland Cayenne	– Australia				
– Typhones 1, 2, 3, 4, 5	– Taiwan				
– Cayenne de Orienta	– Cuba				
– Sarawak	– Malaysia				
– Kew	– India				

(*Continued*)

Table 4. Contd

GROUP 4 Pernambkuco		GROUP 5 Mordilonus – Perolera – Maipure	
– Pernambuco	Brazil	– Milagrena	– Ecuador
– Paulista			
– Boituva – Amarelo		– Perolera	Columbia, Peru
– Perola		– Mariquita	
– Yupi		– Amarillo	
		– Piampa	
– Abacaxi	– West Africa and many other countries	– Manzana	
– Pan de Azucar	Central America	– Tachirense	Venezuela
– Sugar loaf		– Maipure	
		– Bumanguesa	
– Eleuthera	– Florida	– Randon	– Brazil
– Venezolana	Venezuela	– Monte Lirio	– Central America´
– Pina Valera			
– Papelon			

to yellow colour at maturity. An average acid range lies between 0.5 and 1.0% and the total soluble solids (TSS) between 12° and 16° brix. Crown is normally one, is attached to fruit without a narrow neck and has loosely imbricate leaves above. Slips are on the peduncle ranging from 0 to 10, and suckers are in leaf axils ranging from 0 to 3 and reaching a length of 35-40 cm.

Hilo

It is a sub-variety of Smooth Cayenne, selected in Hawaii by Collins (1960), and its cultivation is limited to Hawaii only. It differs from Smooth Cayenne. Its plants are usually smaller, and slips are not produced. Shoots are more and develop early. Fruit shape is more cylindrical, its size is slightly smaller with larger fruitlets. Flesh colour is more yellow having higher percentage of translucence. Fruit deteriorates more rapidly after reaching full ripeness.

Kew

It is a late-maturing variety and is the leading commercial variety in India. Kew is valued particularly for its canning quality.

The plants are vigorous and leaves are long with straight margins. The upper surface is dark green with a superficial brownish-red mottling and the lower surface is silvery-grey or ashy-grey in colour. Leaves often have a short sector of small spines at the tip and also at the base, near its attachment to the stem, where they are irregularly arranged.

Fruit weighs 1.5–2.5 kg, and is oblong in shape, slightly tapering towards the crown. Eyes are broad and shallow; making fruits more suitable for canning. The fruit is yellow when fully ripe and flesh is light yellow, almost fibreless, and very juicy with 0.6–1.2% acid, and its total soluble solids content varies from 12° to 16° brix. Normally fruit will have one crown but occasionally more are present. Slips arising on peduncle are 0 to 10 and the number of suckers produced per plant vary from 0 to 2. This shy-suckering habit is a disadvantage in its multiplication.

Giant Kew

This variety grown in certain regions of India is synonymous to Kew excepting in size of the plant and the fruit, which are larger then Kew as the name signifies.

Charlotte Rothschild

In Kerala and Goa, a variety Charlotte Rothschild is under cultivation, which is similar to Kew in fruit characteristics and taste.

Other varieties of this group are St Michel of South Africa and Baronne-de-Rothschild grown in Guinea.

VARIETIES OF QUEEN GROUP

Queen or Common Queen

This is an old cultivar and is grown mainly in Australia, India and South Africa, where it is favoured for trade of fresh fruit.

The plants are characterized by dwarf, compact habit of growth. Foliage is bluish-green. The leaves are short, stiff, spiny along the margins, and thickly covered with a whitish bloom on both surfaces. The flowers are lilac.

Fruit weighs 0.9–1.3 kg. Peduncle is short; fruitlets or eyes are small, prominent, deep set. When fully mature, the fruit is golden-yellow and internal flesh is deep golden-yellow. The flesh, although less juicy than Cayenne, is crisp (less fibrous), transparent with a pleasant aroma and flavour. The total soluble solids content varies from 15 to 16° brix and acidity between 0.6 and 0.8%. The slips are 0–4 and suckers are 0–3, and both are smaller in size than those of Cayenne.

Mauritius

It is grown in some parts of Meghalaya and Kerala in India. Fruits are of medium size and are of 2 types, deep yellow and red. Fruits of yellow variety are oblong, fibrous, and medium sweet compared to red type. Mauritius is exclusively grown for table purpose. Leaves are yellowish green, spiny throughout the margin. Crown also is spiny in both the types.

Ripley Queen

It is a selection from Queen and is grown in Australia. It has pale-green foliage heavily tinged with red, and fruit is more conical in shape than Queen, with a distinctly flattened top. Fruits have pale-coloured skin and a richer flavour.

Alexandra

This variety is grown in Australia. It is a local selection made in Queensland from the Ripley Queen and is similar to parent variety, but is more vigorous and produces somewhat larger fruits.

Mac Gregor

It is a local selection at Queensland in Australia from variety Queen It is sturdier, broad leaved, more vigorous and produces larger and better shaped fruits.

Z. Queen

This is a sub-variety of Queen, reported from South Africa. It was found as a single unusual plant in a plantation of Queen, and it is supposed to have originated as a result of somatic mutation. It has spiny leaves of Queen but fruits are larger and have comparatively square shoulders. Texture of the flesh and colour are similar to Queen. It also resembles Mac Gregor, sub-variety of Queen.

VARIETIES OF SPANISH GROUP

Red Spanish

It is extensively cultivated in West Indies, Cuba, Puerto Rico and Mexico, and is mainly used for trade of fresh fruits.

The plant and fruit size is intermediate between Cayenne and Queen. The leaves are long, about 1.2 m and spiny. Fruit is rather square in shape and weighs between 0.9 and 1.8 kg. Peduncle is long (20–25 cm) and slender and is often not able to support the fruit upright. Fruitlets are few, about 80, larger than Cayenne; shell is tough and firm, and is orange-red. The eyes are located deep, as in Queen group. Flesh is pale yellow, fibrous with pleasant penetrating aroma and spicy acid flavour; quite different from that of Cayenne or Queen. Core is relatively large. Crown is 20-25 cm long, with long spiny recurved leaves. Slips are 2–8, and are borne very close to fruit. Suckers range from 1 to 3 per plant.

Singapore Spanish

It is grown in Malaysia for canning industry. This is also known as Singapore Canning and Nenasmerah. The leaves are around 50 in number. They are 100 cm long and are slightly narrower than those of Cayenne. This variety has smooth leaves with a few spines near the tip. The fruit is cylindrical in shape, weighing about 1.6–2.3 kg. The fruitlets range between 70 and 110 and have slightly protruding surface with deep eyes. The ripe fruit is reddish orange and flesh is golden-yellow, fibrous and good flavoured, contributing to the quality of the canned product. Crown is 10–30 cm long, frequently multiple and fasciated.

Masmerah

Grown mainly in Malaysia, this is a selection from Singapore Spanish. The plant resembles a typical Singapore Spanish, excepting that it is more vigorous. The leaves are generally spineless. The longest leaf is about 120 cm long and 6 cm wide at the mid-point. Leaves tend to be more erect than those of Singapore Spanish. Inflorescence bears numerous purple florets which are subtended by red bracts. Fruits are

borne on a 30-40 cm long peduncle which is slightly thicker than that of Singapore Spanish. The fruit is cylindrical, weighs 1.5–3.0 kg, and bears 1–12 slips. As Masmerah is closely related to Singapore Spanish, the skin of the fruit is also thick. The flesh is translucent and intensely golden. The TSS content is about 10° brix and acidity is around 0.5%. The crown is large; 50 cm or longer.

OTHER VARIETIES

Abacaxi

It is widely grown in Brazil for local markets. Plants are erect and leaves are 60–65 cm in length with dark green ground colour, and slightly reddish upper surface. The fruit is pyramidal in shape and weighs about 1.5 kg. Fruitlets are small and eyes are shallow. The flesh is pale yellow to almost white, tender, having very small fibres, and with an abundance of juice. Juice is less acidic than Cayenne and general flavour is mild and good. The core of the fruit is small. Keeping-quality of the fruit is poor unless harvested at half-ripe stage. Of late, Abacaxi is considered as a separate group of pineapple. Related cultivars of this group are Pernambuco and Sugar Loaf.

Cabezona

This is grown in Puerto Rico for trade of fresh fruits and for shipping to New York. It is seedless, whereas Cayenne and Red Spanish produce some seeds when grown together in Puerto Rico.

INDIGENOUS TYPES OF INDIA

Jaldhup and Lakhat

These are two local types, both being named after the places of their maximum production. Both fall in Queen group of fruits, being smaller than Queen. Lakhat is markedly sour in taste, whereas Jaldhup has its sweetness well-blended with acidity. Fruits of Jaldhup have a characteristic alcoholic flavour of their own and can be easily distinguished from other fruits of the Queen group.

Simhachalam

In Vishakhapatnam district of Andhra Pradesh, a local variety Simhachalam is grown.

Baruipur Local

It is largely grown in Baruipur, Sonarpur and Joynagar areas of south Bengal. The plants are moderately vigorous. Leaf margins are

heavily serrated. It has heavy slip and suckering habit. Plants are very hardy and can stand adverse climates. Fruits are of small size (weighing between 1 and 2 kg), conical in shape and taper towards the crown. The crown is single and big. Rind colour of the ripe fruit is reddish-yellow. Eyes are prominent, irregular and deep set. Flesh is yellow, fibrous, little stringy and sour to taste. It is neither suitable for canning nor for table purpose.

Haricharanvita

It is grown in some pockets of Siliguri sub-division of Darjeeling district and Sadar sub-division of Cooch Behar district. Its plants are vigorous, leaves are long and slender, and leaf margins are heavily serrated. It has heavy slip and suckering habit. Plants are very hardy and can stand adverse climates. Fruit weight ranges from 0.75 to 2.0 kg. Fruit is conical in shape and tapers towards the crown. The rind of the ripe-fruit is greenish yellow; skin very thick, and eyes are prominent, irregular and deep set. The flesh is yellow, fibrous, sweet to taste but a little stringy. It has 1 or 2 crowns per fruit which are of big size. This variety is not suitable for commercial production.

VARIETAL IMPROVEMENT

The breeding in pineapple aims at a vigorous plant, having a short cycle and resistance to diseases (especially mealy-bug wilt); with broad, short and smooth leaves; and cylindrical fruit, well coloured, with flat eyes, on a short but strong fruit-stalk; a small ratio of leaf to fruit; with firm flesh, well coloured, not fibrous with high drymatter content, moderate acidity, high vitamin C and a narrow axis; early formation of 1 or 2 shoots and presence of 1 or 2 slips at least 2 cm below the fruit base (Etudes sur Ananas, 1977).

Cayenne is the world's major canning cultivar and many of the breeders use it because of its high proportion of good characters. Cayenne needs to be improved for its larger and more vigorous root system, more cylindrical fruits, which ripen more uniformly from base to apex, deeper yellow and crisp flesh, better quality of winter-produced fruits and resistance to wilt.

Desirable Plant and Fruit Characteristics

A good fruit is long, cylindrical and broad-shouldered, with large, flat-eyes and a small core. It should be low-set on a short fruit-stalk, bearing not more than 3 slips, all set well below the base of the fruit. The stem should be relatively short, with at least 2 suckers, originating close to the ground to ensure a stable ratoon plant. The number of suckers and

Table 5. Ideal plant and fruit characteristics for canning and export

Plant characters	Fruit characters		
Vegetative growth and development	Required for canning and export of fresh fruits	Required for canning	Required for export of fresh fruits
– Rapid growth	– High mean weight	– Broad, flat fruitlets	– Yellowish orange skin
– Semi-erect growth pattern	– Homogenous ripening from bottom to top of fruit	– Shallow blossom cup	
– Short, wide leaves	– Fruit well filled		– Small to medium crown
– Spineless or few spines only at the tip	– Firm but not fibrous, yellow flesh	– Flesh slightly translucent when ripe	
– Less than 3 slips not closer than 2 cm to the base of the fruit	– Firm epidermis		
– Low, well-developed suckers at the base of the plant	– High sugar content		
	– Moderate acidity		
– Short- to medium-fruit peduncle easily able to bear ripe-fruit	– High ascorbic acid	– Small core	
	– Pleasant flavour	– Large crown	
– Resistant or tolerant to main pathogens and parasites, *i.e.* mealy bugs, nematodes, *Phytophthora*, *Fusarium* and *Penicillium*			
– Able to adapt to irregular water supply			
– Able to adapt to wide range of soil types			

the length of the fruit-stalk are influenced by the growing environment.

Although Smooth Cayenne can be regarded as an ideal type in many respects, it could be improved by selection within its variable populations. Breeding work carried out at the University of Puerto Rico by crossing Smooth Cayenne with Red Spanish resulted in 2 hybrids. They are PR 1-56 and PR 1-67. Leaves are spiny in PR 1-56 and are spineless in PR 1-67. In both average fruit weight is about 2.5 kg. PR 1-56 has white flesh and PR 1-67 has pale-yellow flesh. PR 1-56 is resistant to mealy-bug wilt and the other one is tolerant.

Feng Shan branch station of Tari, Taiwan, also released 2 hybrids, Typhone No. 1 and Typhone No. 3. In both, plants are dwarf and high-yielding. The fruit shape is cylindrical in Typhone No. 3.

The characteristics most commonly sought after by the canning industry and for export of fresh fruits of pineapple are listed in Table 5 (Py *et al.*, 1987)

Mass Selection Methods

The simplest method of selection is eliminating unsatisfactory plants. Defect in plant-type may be marked by lack of vigour; hence selection should be practised on a vigorous plant-crop, which matures in summer, when desirable and undesirable characters are most clearly expressed. Selection should commence about a month before the fruits reach maturity so that they can be used in assessing desirability of the plant-type.

To save time, a preliminary assessment of the area can be made to determine relative proportion of desirable and undesirable types. If the former predominates, rejected plants may be labelled, and vice-versa.

As the fruit is harvested, selected tops should be reserved for planting in the following autumn. The slips on selected plants may be left on the parent fruit-stalk until required for planting.

***In-Vitro* Culture**

In-vitro culture of pineapple was started using apex of the crown (Mapes, 1973), slips (Sita *et al.*, 1974), axillary buds from crown (Mathews *et al.*, 1976), and more recently syncarp (Wasaka *et al.*, 1978). Though plantlets are easily obtained, there is a high percentage of variation (Wasaka, 1979). Depending upon the origin of the material and the type of environment used for culture, *in-vitro* culture could be used either for obtaining variants or for accelerated propagation.

6

Climate and Soil

NATURAL habitat of the pineapple is a humid tropical region. Most of the cultivated pineapples are grown in the region between 25° north and south of the equator (Collins, 1960). The most northerly location for the field culture of the pineapple appears to be Assam at a latitude of 30° 45' N (Hayes, 1960), and most southerly location is Port Elizabeth in South Africa at 33° 58' S latitude (Strauss, 1960). Pineapple is an evergreen perennial plant which does not have dormancy and will continue to grow as long as environment favours.

CLIMATE

Extremes of climates such as occurrence of frost and intense solar radiations associated with very low humidity are not favourable for pineapple cultivation. The plant is grown mostly at or near the coast or at the island areas as well as in the interior, so long as temperatures are not at extremes. The optimum temperature range for successful pineapple cultivation is between 15.6° C and 32.2° C (cited by Malan, 1954). Leaves and roots grow best at 32° C and 29° C, and their growth practically ceases below 20° C and above 36° C. A high temperature at night is deleterious and a difference of at least 4° C between the day and the night temperature is found desirable (Bartholomew and Kadzimin, 1977).

High temperature over 35° C is unfavourable for the development of fruits, especially if the relative humidity is low. Strong and direct solar radiations cause sun-burn of fruits, which is characterized by desiccation, partial drying and cracking of fruits, and is eventually associated with less juice content. High temperature has no effect on the growth of the plant itself. In general, pineapple needs a sunny climate, though there are no exact figures on hours of sunshine or of solar radiations required for flowering and higher productivity.

The sensitivity of pineapple to frost and cold winds restricts altitudes up to which it can be cultivated. It can be grown up to an elevation of 1,100 m above the sea level, if these places are free from frost, have a relatively high atmospheric humidity and an average rainfall of 760-1,000 mm.

Pineapple is resistant to drought but requires a rainfall of at least 760 mm during summer. Higher rainfall is not unfavourable, since this is usually linked with higher atmospheric humidity and cloudiness;

whereby the risk of fruit being damaged by sun-burn is reduced. In such areas, good drainage is important because the root system of pineapple plant is said to be very sensitive to waterlogging (Collins, 1960; Teiwes and Gruneberg, 1963). Optimum annual rainfall for commercial pineapple production ranges from 1,000 to 1,500 mm (Collins, 1960; Teiwes and Gruneberg, 1963; Py and Tisseau, 1965). Pineapple shows a remarkable ability to grow and produce crops under a wide range of rainfall; ranging from as low as 565 mm on the Island of Molokai, Hawaii (Noffsinger, 1961) to 3,550 mm at Neufchateau, Guadeloupe (Py *et al.*, 1968). However, rainfall requirements vary with atmospheric humidity. In coastal areas, where atmospheric humidity is high, growth and productivity will be normal even with low rainfall. In hot and interior areas, high rainfall distributed over a longer period is required. In areas where rainfall is less or confined to a short duration in a year, protective irrigation during dry season or water-conserving management practices such as use of plastic, polyethylene or dry-leaf mulches are necessary.

SOIL

Soil requirement specifications are minimal for pineapple cultivation. It comes up well in any type of soil. Pineapple is grown in peat soils in Malaysia, quartz sand in Australia, Africa and Taiwan and highly weathered Kaolin clays and iron and aluminium oxides in Hawaii, tropical America, South-East Asia and parts of Africa (Collins, 1960; Py and Tisseau, 1965; Teiwes and Gruneberg, 1963). The plant is particularly sensitive to soil being waterlogged. Hence in laying out a pineapple plantation care should be taken to ensure proper drainage. Medium-to-heavy loams, rich in humus, and having a slightly acidic reaction are more suitable. Plant prefers soil pH of 5.0–6.0. Soils with a higher pH are unsuitable owing to the development of lime-induced iron chlorosis (Malan, 1954).

Practically every soil is suitable for growing pineapple if the following two requirements are fulfilled.

1. Good retention of moisture, drainage and aeration of the soil. No hard-pan in sub-soil which could harm supply of water and cause waterlogging.

2. Calcium content of the soil must be low. The pH must not be more than 6.0.

In India, pineapple is grown on a wide range of soils. In Kerala, it is grown on marginal lands, not suited for rice and other irrigated crops. While it is reported to grow best on sandy and loamy soils of the West Coast. The experience in north-eastern regions shows that fruit grows

well in a wide range of soils, from the new alluvium of the plains to old alluvium of the sub-mountainous tracts as well as the lateritic soils of the hills so long as land is not waterlogged at any time of the year. In fact, no other fruit-crop is probably so adaptable in its soil requirements as is pineapple.

7

Propagation, Planting and Plant Density

PROPAGATION

PROPAGATION of pineapple like most other fruit crops is exclusively done by vegetative means. In case of hybrids, progenies evolved through seeds are also vegetatively propagated. The most common plant parts used for propagation are suckers and slips. Crowns are also used with varying degrees of success. Plantlets arising from old plants usually carry all inherent characteristics of the parent plant. These plantlets are in the form of suckers, shoots, slips and crowns.

Suckers arise and grow from buds below the ground level. They are sparsely produced. Shoots are leaf-branches arising from the buds in the axils of leaves above the ground level. Both of them look-like daughter plants by the side of the mother-plant. They emerge out as the mother-plant flowers, and can be seen growing fast when fruit develops. After the fruit is harvested from the mother-plant, these grow still vigorously and bear fruit in the forthcoming season. This is known as the ratoon crop.

Slips arise from fruit-stalks. They are comparatively smaller than suckers, and are borne more in number per plant than suckers. They cannot grow into individual plant *in situ* and have to be transplanted in the soil.

Crown grows on the top of the fruit. It is the vegetative growth at the top of the fruit, attached to the central core of the fruit. It is called crown as it adorns the apex of the fruit. Of the 3 types of planting materials, suckers are the largest material in size. Besides these, others are discs, hapas, butts or stumps.

Fruit-stalks cut into bits known as 'discs' can also be used for propagation, but their use in field is very limited.

Hapas are shoots produced at the base of the peduncle. They are intermediate in size between shoots and slips.

Butts or stumps are the stem parts of the plant that have borne fruits. These consist of entire plants after the fruits have been harvested and from which the base of the stem, roots, leaves and peduncle have been removed. The older they are, the less suitable they will be as a plant.

Butts are not generally recommended as a planting material and should only be used as the last resort.

Methods have been devised to speed up rate of asexual reproduction in pineapple for breeding work or when planting material is limited. An axillary bud is present in the axil of each leaf of a mature stem, but only 0–3 shoots are produced per plant. When some of the dormant axillary buds are cut-off with a little of the adjacent stem tissue, they can be induced to form new plants. The leaves and roots are removed and stem is cut longitudinally into 6–8 pieces. The stem is then cut transversely into triangular slices of about 2.5-cm thickness, each containing 1 or 2 buds. The pieces are fumigated to check organisms which would cause their rotting. The pieces are then planted in the sterilized shaded beds, with the inner point downwards, 5-cm apart and covered with soil to a depth of 1.2–2.5 cm. They should be watered sparingly during the first 10 days to harden off the sections. Some of the buds grow and develop roots. The plantlets are removed after 3–5 months and are transplanted into nursery beds. They will produce mature plants in 2½ - 3 years. The buds in the axils of shoot and crown leaves can be used in a similar way.

Choice of Planting Material

Performance of plants as characterized by vigour, growth rate, time taken for bearing and fruit size and quality varies with the type of material used for planting in pineapple. Besides the type, size of the planting material also results in the variation in the performance of the subsequent plants. With different types and sizes of planting materials, a number of management difficulties crop up on account of the poor rate of plant establishment, uneven growth of plants, and uneven flowering and harvesting, stretched over a long time. Besides, uniform cultural operations cannot be taken up, and ultimately plant-wise operations have to be followed, which mar the efficiency of the labour and other inputs, resulting in increased cost of production. In a mixed planting, a few plants are in flowering while the others are ready for harvest. This state of plant growth poses problems for getting good uniform ratoon crops also. Therefore, it is advisable to use uniform-size material of a monotype for uniform growth of plants.

Hence, it is imperative to know, what is the right type and size of planting material to be selected for commercial planting. Studies carried out at Basti (Teaotia and Pandey, 1966) and Bangalore (Chadha *et al.*, 1974) have indicated the superiority of slips over suckers; which in turn are found better than crowns. Both in suckers and slips, larger planting material resulted in vigorous plants. Neither too big nor too small slips or suckers resulted in more flowering, and the larger grade material

resulted in the more staggered flowering period. Smaller was the size of the slips or suckers, earlier was the fruit maturity. Slips yielded better quality fruits and yields were at a par with the highest yield obtained with the largest suckers. Of the 3 types tested, crowns resulted in the least vigorous plants. Their harvesting took more time. Besides, their survival percentage was less and yield was poor. But fruits produced were of good quality. In the overall analysis, slips weighing from 300 to 450 g were reported to be the best planting material.

Among the types and sizes of propagules tried, slips and suckers, weighing around 350 g and 450 g, were found the best in terms of yield and quality for Kew pineapple under Coorg (Karnataka) conditions (Singh *et al.*, 1978). In Jorhat (Assam), suckers weighing 501–750g and slips weighing 301–400 g were found ideal planting material (AI C FIP Cell I, 1982), while suckers weighing 501–1,000 g were best for planting in Thrissur (Kerala) (Varkey *et al.*, 1984).

It can be concluded that in the event of non-availability of slips, suckers weighing around 500 g are ideal, and in the event of non-availability of sufficient number of suckers, due to poor suckering habit of the varieties like Kew, slips weighing around 350 g are the best (Figs 4, 5).

However, shortage of propagules in pineapple is felt universally. Mass multiplication of propagation material is vital to bring fresh area under cultivation. This is possible only when a number of plantlets can be obtained from a single mother-plant, unlike a few suckers or slips. A possibility of using leaf-cuttings from crowns of cvs Kew and Smooth Cayenne for multiplication of planting material has been shown. Ten to fifteen leaf-cuttings are made from each crown. However, these cuttings will take even more time than crowns for flowering and thus are only recommended when sufficient planting material is not available (Dass *et*

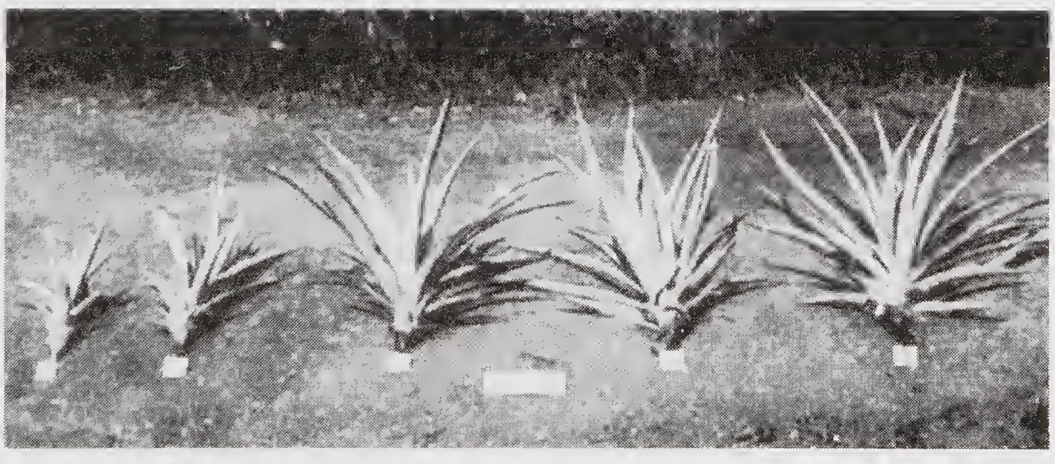

Fig. 4. Suckers of different size-grades

Fig. 5. Slips of different size-grades

al., 1976; Fitchet and Venter, 1988).

PLANTING

Suckers and slips are usually preferred for planting since they flower comparatively earlier than crown. Propagation by crown is very limited, and use of stumps or discs for planting is very rare in India.

Time of Planting

The time of planting dictates the season at which the first plant-crop is obtained. Planting time is very important in view of the natural flowering period, which differs from region to region. By the time of flowering, if plant does not attain optimum physiological maturity, either it will escape flowering and flower in the next season, or if flowering is induced in the same season, the plant will bear small fruits. Hence the ideal time of planting would be 12-15 months before the peak flowering season under natural conditions, which varies from December to March in different regions. Time of planting also varies from place to place, depending upon the onset of the monsoon and intensity of precipitation. Pineapple is mainly planted just at the onset or at the end of the monsoon in order to avoid heavy precipitation in the pre-establishment period of the plants. For western India, Gandhi (1949) recommended planting during September-November. In Assam, planting is done during August-October, and in Kerala during April-May. The best time for planting in Chethalli (Coorg) was found to be April-June (Chadha, 1977). A late planting in September delays crop at least by 7-9 months. The peak flowering under this condition was observed during January-March. Best planting time in north Bengal district is October and November, and in the other districts it is in June-

July (Directorate of Agriculture, Govt of West Bengal, 1976).

Pre-treatment of Planting Material

Before planting, suckers are sorted out into larger, medium and small to avoid competition between plants of different sizes. Uniformity of planting material must be ascertained in a plot for the ease of carrying out a particular cultural operation at a time. The plant material is cured by removing scaly leaves from about 2–5 cm of the stem base to expose root initials and by trimming lower end of the stem with a knife and keeping it exposed for 4–5 days before planting. After removing scaly leaves, planting material should be treated with monocrotophos (0.15%) and carbendazim (0.1%) solution to protect against mealy bugs and heart rot, respectively. Stripping of lower leaves facilitates initial rooting and establishment of plants.

Planting System

The planting system varies depending upon the topography of land and rainfall. There are 4 planting systems in vogue, viz. flat-bed planting, furrow planting, trench planting and contour planting (Chadha, 1977). Before planting, land is ploughed thoroughly, followed by harrowing to give fine tilth to soil.

Flat-bed planting. It is commonly followed in West Bengal, mostly in plains, where there is no problem of soil erosion. Planting is done by dibbling in pits 15–20-cm deep. Provision is made to drain-off excess water in high rainfall areas and to irrigate in scanty rainfall areas. Flat-bed planting is also practised in irrigated areas in Bombay province of western India (Gandhi, 1949).

Furrow planting. This is followed in coastal plains of Kerala where natural precipitation is moderate, fairly distributed, but not intensive, and crop is grown without irrigation. Planting in this system is done in 30–45-cm deep furrows alternating with 1.2–1.5-m broad ridges.

Trench planting. Trench planting envisages at sideward anchorage to plants. Dhareswar (1950) recommended growing of pineapple in 45.72 cm deep trenches in view of the soil moisture conservation. Generally, about 30–45-cm deep trenches are opened at a distance of 1.0–1.5 m. Two kinds of trench planting such as single-row and double-row are followed; treble-row and four-row trench plantings are also seen occasionally. Single-row trench system is common in hill-side plantations of Kerala, Assam and Tripura, where soil slope is gentle and soil erosion is a problem because of the moderately heavy rains. Double-row trench is very widely followed and popular in Karnataka, Kerala, Assam, Tripura, West Bengal and Goa and wherever plantations are in plains, whether

crop is grown with or without irrigation. The field is laid out into trenches alternating with mounds. Trenches are made always across the slope. In each trench, 2 shallow furrows about 10–15-cm deep and 15-cm inside from the edge of the trench are opened and suckers or slips are planted in these furrows. The plants in two rows within the trench are so arranged that they are not exactly opposite to each other (Fig. 6).

The advantage of treble-row trench and four-row trench over double-row trench is that more number of plants can be accommodated per unit area. Experiments at the Indian Institute of Horticultural Research have revealed that the double-row trench system is better than three-row and

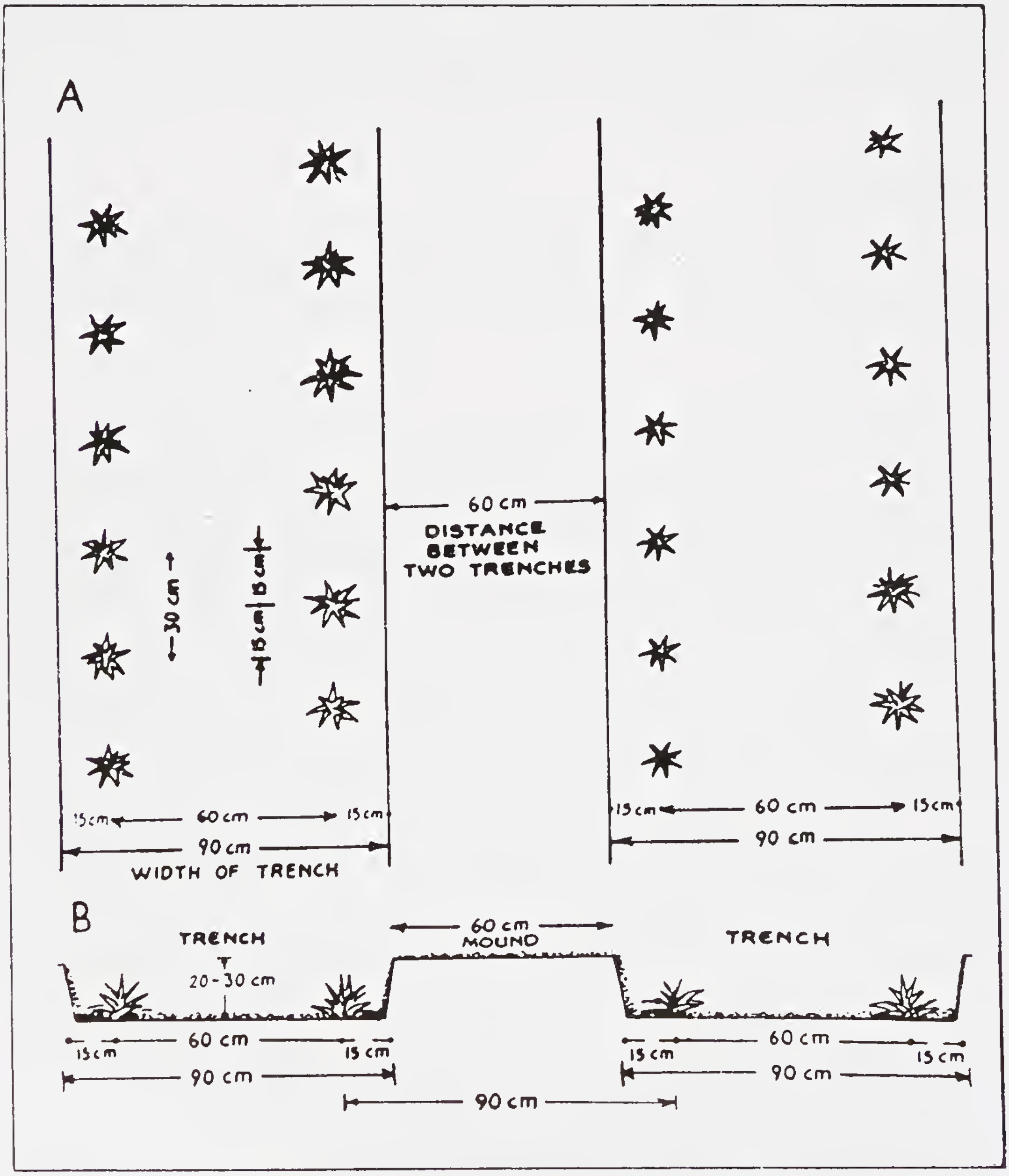

Fig. 6. Layout of pineapple-plot for population density of 43,500 plants/ha

four-row trench systems in view of the convenience in farm operations (Dass *et al.*, 1976). The depth of the trench should be about 22.5–30.0 cm (Reddy and Prakash, 1982; Radha *et al.*, 1990), and this is important for plant-crop than ratoon crops.

Contour planting. This system is commonly seen in hill-side plantations of Assam and Tripura, where rainfall is high and the soil is subjected to erosion. Planting is done in terraces cut by digging contour trenches, which catch run-off water along with silt and serve as drainage channels. Spacing between 2 contour parallel lines of plants and width of the terrace depend on the degree of slope.

Pineapple being a shallow feeder should not be planted very deep. About 10-12 cm of the basal portion of the sucker/slip should be below the soil while planting. Deep planting should also be avoided to prevent soil entering into the heart of the plant, which can kill the plant. While planting, sucker/slip should be set firm by pushing soil around and pressing it hard.

In most of the areas neat planting of pineapple is practised. Dhareswar (1950) and Naik (1963) recommended growing pineapple under partial shade of coconut and young mango trees in plains of south India, where sun is severe and rainfall is scanty.

PLANT DENSITY

Plant spacing or density of pineapple depends on the growth of the plant and system of planting. Adoption of low planting densities has been the major constraint in India, contributing towards high cost of production per tonne of pineapple. One of the ways to reduce cost of production is to increase yield per unit area by following high-density planting.

For Assam, Chowdhury (1947) recommended a spacing of 60 cm within a row, 90 cm in between the rows and 120 cm in between the trenches, accommodating 15,000 plants/ha. In western India, the practice is to accommodate about 10,000 plants/ha under flat-bed system at a distance of 90 cm × 90 cm (Gandhi, 1949). In Kerala, plants are spaced at 45–60 cm within a furrow or trench opened, 1.2–1.5-m apart under the furrow planting or single-row trench planting, accommodating 14,000 plants/ha. In double-row trench (Fig. 7), plant population varies from 15,000 to 20,000/ha (Chadha, 1977). Unlike India, planting density followed in other pineapple-growing countries is much higher.

In Hawaii, plant density followed is 40,000-45,000 plants/ha. In the Philippines, plant density of 62,000 plants/ha is commonly followed (IIFT, 1968). Wee (1969) reported as high as 71,758 plants/ha to be optimum for Singapore Spanish variety under Malaysian conditions.

Fig. 7. A view of pineapple plantation in Kerala — Note the distance between beds and rows (20,000 plants/ha)

Planting more than 45,000 suckers/ha was found to reduce fruit size (Collins, 1960). While total yield of pineapple increases with increased plant population, fruit size reduces with closer spacings. An ideal fruit size for canning is 1.8–0.2 kg, without crown.

According to Waithaka and Puri (1971), the yield of grade I fruits decreased with increasing population density beyond 60,000 plants/ha, and yield of grade II fruits increased steadily. Trials conducted at the Indian Institute of Horticulural Research, Bangalore, have revealed that fruit length, breadth and canning ratio did not vary significantly with varying plant densities ranging from 43,560 to 63,758 plants/ha (Fig 8; Chadha *et al.*, 1973).

Spacing followed for 63,758 plants/ha was 22.5 cm from plant to plant, 60 cm from row to row and 75 cm between beds. Fruit size, quality and canning ratio were not adversely affected by this planting density. The possibility of reducing spacing further was explored at different centres under different agroclimatic regions of the country under the All-India Co-ordinated Fruit Improvement Project. Population densities ranging from 49,300 to 111,000 plants/ha were compared. Dass *et al.* (1978) recommended a spacing of 25 cm × 60 cm × 90 cm between plants, rows and beds for Kew pineapple under two-row system, resulting in a plant density of 53,300/ha in Bangalore, keeping in view of the ease of carrying out various cultural operations; though the fruit yield increased

Fig. 8. High-density planting in Kew pineapple

with increasing plant densities up to 111,000/ha. A plant density from 53,300 (25cm × 60 cm × 90 cm) to 59,200 (25 cm × 60 cm × 75 cm) was also found ideal, both in irrigated and rainfed areas of Coorg, Karnataka (Dass *et al.*, 1978).

Decrease in fruit weight was quite evident when plant-to-plant spacing was reduced to 20 cm and row-to-row to 40 cm irrespective of the spacing between beds. Plant densities of 53,300 and 59,200 plants/ha were found ideal for Kerala as against traditional planting density of 15,000 plants/ha with a spacing of 45 cm × 60 cm × 180 cm in rows, between rows and between trenches. Highest cost: benefit ratio of 1:4.2 was observed in planting densities of 53,300 and 59,200 plants/ha at Thrissur (Kerala) (Annual Report, AICFIP Cell I, 1978), but the density at 59,200 plants/ha was found inconvenient for carrying out cultural operations as the inter-trench spacing is reduced to 75 cm only as compared to 90 cm in 53,300 plants/ha. A plant density of 53,300 plants/ha was recommended in Jorhat (Assam) also (AICFIP, 1978). The average fruit size was reported to be reduced with a plant population of 111,000/ha in Bangalore, Coorg, Thrissur and Jorhat. However, fruit size did not differ much with varying plant populations ranging from 49,300 to 60,000/ha. In high rainfall and fertile areas of West Bengal, planting densities varying from 43,500 to 49,300 were recommended, and for the rest of the areas, 25 cm × 60 cm × 90 cm spacing was recommended, accommodating 53,300 plants/ha. However, Mukherjee *et al.* (1982) recommended 63,758 plants/ha spaced at 22.5 cm × 45 cm × 90 cm for

Queen pineapple in Baruipur (Calcutta) as well as for plains of south Bengal for high yields of good quality fruits and for more suckers and slips production per unit area. Trials conducted at Pineapple Research Station, Nayabunglow, Meghalaya, have shown that 43,500 plants/ha were ideal (Khongwir and Das, 1978).

Spacing for Different Plant Populations per Hectare

The following is the spacing required for different plant populations per hectare.

Plant population per hectare	Distance (cm)		
	Plant-to-plant within a row	Row-to-row	Trench-to-trench
43,500	30	60	90
53,300	25	60	90
63,700	22.5	60	75
		or	or
	22.5	45	90

At Hessaraghatta, rate of ratooning was compared in traditional and

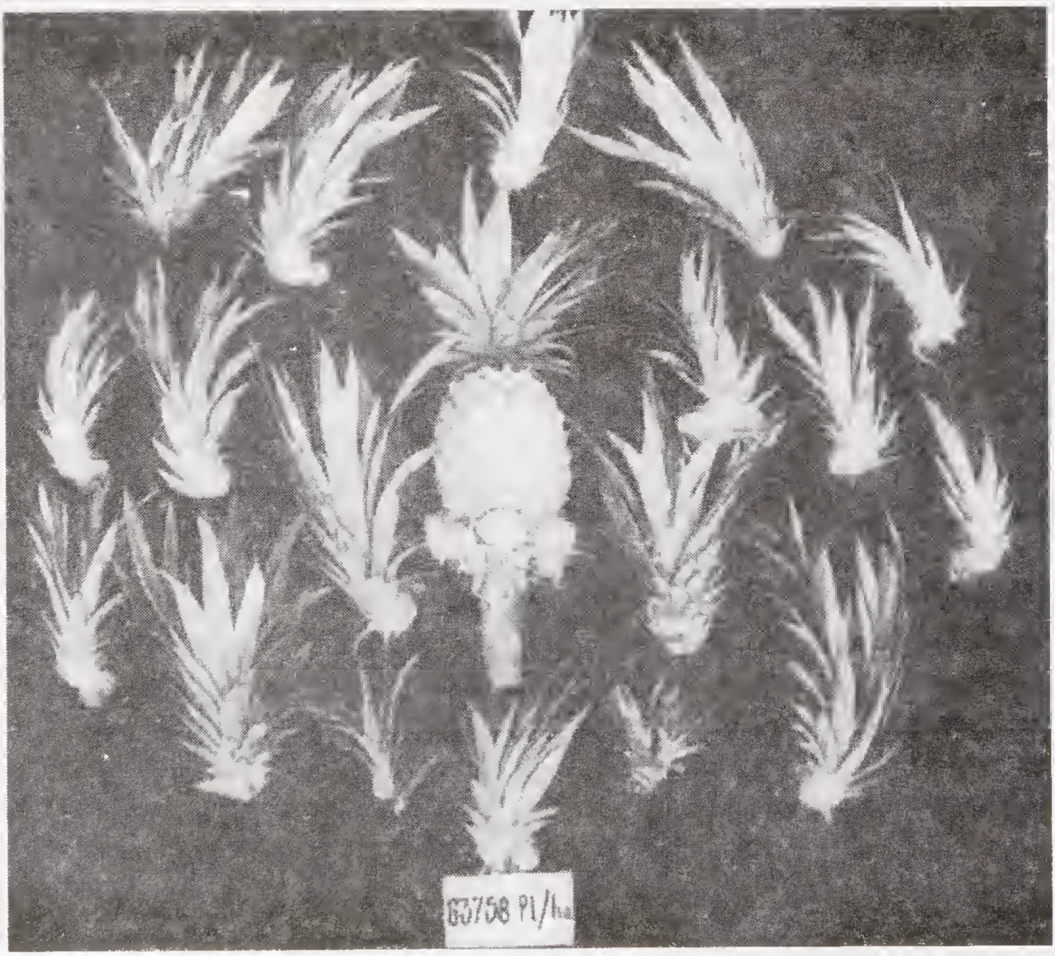

Fig. 9. Large number of slips are produced per plant in high-density planting

high-density planting of 55,555 plant/ha. In this, 2 successive ratoon crops harvested at 12 monthly interval amounted to 50.7 and 53.8% of the plant crop yield (Chadha, 1977). The yield of the first and second ratoon crops is to an extent of 50-60% and 40% of the plant-crop in Hawaii and Australia.

High-density planting, besides increasing the yield, is associated with other advantages like less weed infestation, protection to fruits from sun-burn and increased production of suckers and slips per unit area, and non-lodging of plants (Fig. 9) . Close planting also saves on the cost of providing shade to fruits, as it provides natural shade through upright orientation of the apical leaves (Fig. 10), and eventually results in uniformly-coloured lustrous fruits. In Assam, about 20-25% of fruits develop sun-burn in the absence of adequate shade. High-density planting also results in overlapping of basal leaves forming a sort of natural covering over the soil; preventing evaporational losses and therby resulting in moisture conservation. Under dense planting a micro-climate with high humidity will be created around the plant which is congenial for growth and fruiting. It is also possible to take at least 2 ratoon crops under high-density planting. High-density planting is recommended to accommodate as many number of plants as possible while ensuring

Fig. 10. Upright and overlapping leaves provide natural shade to fruits in high-density planting

sufficient space to carry-out cultural operations.

Soil moisture and fertility influences plant growth and indirectly determines spacing required per plant and eventually planting density. In overall analysis, a plant-to-plant spacing of 22.5 cm and a row-to-row spacing of 45 cm appear ideal. Where pineapple plants grow luxuriantly with long leaves, a wider spacing of 90 cm between the trenches seems to be required, but in places where growth of the leaf is moderate, a trench-to-trench spacing of 75 cm appears adequate. However, two row-trench system of planting has been found to be the best universally.

A plant density of 63,000 plants/ha (22.5 cm × 60 cm × 75 cm) has been found ideal in sub-tropical and mild humid areas of Bangalore. In hot and humid areas of Kerala, Karnataka and West Bengal, a plant density of 53,000 plants/ha (25 cm × 60 cm × 90 cm) performs well. In rainfed, highly fertile and hilly areas, like north-eastern states, a plant density of 43,000 plants/ha (30 cm × 60 cm × 90 cm) has been recommended. The yields recorded under high-density planting are in the range of 70-105 tonnes/ha. The increase in yield per unit area is in the order of 45-85 tonnes/ha. In nutshell, adoption of high-density planting does not hamper fruit size, quality and canning recovery.

8
Nutrition

OF the 16 nutrient elements essential for plant growth, nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), sulphur (S), iron (Fe), zinc (Zn), copper (Cu) and boron (B) have a distinct role in metabolism of pineapple, in the production of drymatter and as a constituent of different enzymes. The morphological and physiological peculiarities of pineapple-plant could deviate the normal role of these nutrients in plants. Hence, the role of different nutrients, as observed in a number of nutritional experiments carried out on pineapple, with graded doses of nutrients, is enumerated in this chapter.

MACRONUTRIENTS

Nitrogen

Nitrogen is an important constituent of proteins and their precursors, which form about 7% of the drymatter of the pineapple-plant. A sufficient supply of nitrogen is, therefore, the prime necessity for ensuing vital processes of the plant. Application of nitrogen promotes formation of leaf material and increases weight of stem, but it does not increase root formation in proportion to the weight of the whole plant (Sideris and Young, 1950). In addition to increase in the weight of the fruit, its diameter also increases (Py *et al.*, 1956, 1957a); probably through increased plant growth as the reserves are translocated from stem and other vegetative parts into the developing fruit. Besides flower formation depends on the ratio of the nitrate to carbohydrate in the plant, and it retards with increased application of nitrogen. Level of the nitrogen in D-leaf must remain at more than 1% of the total drymatter (Martin-Prevel, 1959a).

Under severe N deficiency, plant growth was observed to be very poor with no production of suckers, slips and fruit. Root growth was also limited, and only a few new roots were formed (Cibes and Samuels, 1958). Under adequate N nutrition, young leaves are bluish-green with a purplish midrib which becomes reddish in older leaves (Malan, 1954). Inadequate N gives a yellowish colour to leaves, with the red being more predominant at the midrib. N-deficient plants of Singapore Spanish in sand culture were found stunted and yellow with delayed fruiting and deformed fruits (Kanapathy, 1959). De Geus (1961) reported pale yellow to orange leaves with N deficiency, especially the older leaves. Both

young and mature leaves were chlorotic. Srivastava (1963) observed stunted growth with N deficiency; emerging leaves were small and pale-green with necrotic tips. Older leaves were pale-green and had developed necrotic margins. A chemical study by Sideris (1955) showed that there was low chlorophyll and protein-N in nitrogen-deficient leaves than those receiving nitrogen.

Excess N results in vigorous leaf development at the expense of fruiting.

Phosphorus

Phosphorus is present in the plant not only in various organic forms such as nucleic acids, phytin, phosphatides and as constituent of enzymes, but also in inorganic forms, which actively participate in energy transport mechanism of the plant. In all reactions of synthesis and decomposition of carbohydrates, phosphoric acid has a key role. From these reactions, plant obtains energy for its vital processes. However, pineapple absorbs very little of phosphorus, indicating that pineapple is able to use effectively little quantities of P_2O_5 it absorbs. Py *et al.* (1956) could establish no significant effects resulting from application of a phosphatic fertilizer even on a soil having relatively low phosphate contents. However, according to Nightingale (quoted by Py *et al.*, 1957a) heavy dressing of phosphorus accelerated fruit formation and ripening. Phosphorus application had shown no marked effects on fruit yield and quality (Dunsmore, 1957). Research carried out at the Indian Institute of Horticultural Research, Bangalore, revealed that phosphorus had no role in improving either fruit yield or quality (Chadha *et al.*, 1972). However, application of P was found to promote development of ratoons and had resulted in increased yields (Pan, 1957; Garcia and Treto, 1988; Mustaffa, 1989). P_2O_5 was also found to have a complementary effect on yield when applied together with N or K. Collins (1960) stated that phosphate deficiency reduced plant vigour and production of planting-material.

With P deficiency, colour of the new leaves becomes dark-purple green without any sign of chlorosis (Nightingale, 1942; Cibes and Samuels, 1958). With the absence of phosphorus, plant growth was poor; there was no production of fruits, slips and suckers. Chlorotic areas on leaves were apparent as leaf age advanced (Cibes and Samuels, 1961). P-deficient plants resulted in reduced leaf number and growth (Srivastava, 1963). Leaf size and colour was not affected in the early stages. However, older leaves had marginal chlorosis with large bronze and purple chlorotic areas. In a sand-culture study in Malaya (Kanapathy, 1959), P deficiency resulted in dark green, purple-ribbed leaves, and fruits of such plants were sour and watery.

Higher amounts of P had depressing effect on growth (Malan, 1954). Excess P depressed yield, hastened fruiting and increased number of cull-fruits (Samuels *et al.*, 1956). Yield reduction with high P was attributed to reduced N uptake (De Geus, 1961).

Potassium

Potassium is found in inorganic forms everywhere in the plant; where most of the physiological activities are in progress, particularly, in young leaves and meristematic tissues. Formation of sugar and starch, of organic acids, and of hardened tissues, reduction of nitrates and consequently synthesis of proteins are largely dependent on the quantities of potassium present. Potassium is indispensable in transportation of photoassimilates from leaves to organs of storage and to organs of utilization in the physiological processes. K is involved in stomatal regulation and water economy also.

A copious supply of potassium increased stem weight to a greater extent than the weight of the plant, leading to the development of a strong stem with higher accumulation of starch and protein (Sideris and Young, 1945). Pineapple has high potash requirement soon after planting, and its requirement is highest at the time of fruit formation and ripening. Potassium has been reported as the factor controlling fruit quality (Py *et al.*, 1957a). Fruits from potash-deficient plants were small with poor quality having low sugar and acid contents (Kanapathy, 1959). Diameter of fruit-stalk and the number of fruits standing erect on the plant were found more when the proportion of potassium was high in the total cations applied (Martin-Prevel, 1961).

Potassium deficiency leads to appearance of brown spots on green parts of the leaves and withering of leaf tips. The leaves are also shorter and narrower than normally nourished leaves (Py *et al.*, 1956). Initially, K-deficient leaves remain green with only leaf-tip drying, and necrotic spots are formed on blistered areas which appear later on leaf surfaces. These symptoms appear first on older leaves and progress to younger ones (Cibes and Samuels, 1958). Fruits also from K-deficient plants were small, late maturing, low in total solids and acids (Cibes and Samuels, 1961). Martin-Prevel (1959b) found senescent and recently matured leaves to drop and develop numerous small translucent yellow spots (3 mm diameter). These symptoms were more pronounced as leaves aged. Spots appeared as raised areas on the upper surface and later spread over the entire leaf, excepting the basal 15 cm. They coalesced into large yellow spots and finally the centre of the yellow spots became necrotic. Leaves of K-deficient plants were markedly smaller and had necrotic tips and margins (Srivastava, 1963). Absorption of potassium

continues actively even after flower induction (Lacoeuilhe, 1973), and represents double the mass of nitrogen in the plant until flower induction (Lacoeuilhe, 1978).

Calcium

Like all other plants, pineapple also needs calcium as it is indispensable for cell-wall formation and for cell division. Accumulation of calcium in leaves is characteristic of aging and maturation. Though calcium needs of pineapple are small, but an excess of cations in the soil leads to calcium chlorosis.

Calcium is distributed uniformly over the whole leaf in pineapple; whether it is chlorophyllous or non-chlorophyllous tissue of the leaf (Sideris and Young, 1945). Calcium accumulation in stem is twice as much as that in leaves. It accumulates especially in meristematic tissues of the stem apex. With the formation of placenta and fruit, calcium content of stem gets reduced (Sideris and Young, 1951). Calcium seems to play an important part in the flower-bud differentiation and in fruit formation (Sideris and Young, 1950).

Calcium deficiency is observed in young leaves; as calcium is immobile in plant. Calcium deficiency leads to pale-green leaves with some yellow mottling and new leaves show dieback of tips (Cibes and Samuels, 1958). As deficiency progresses, leaves develop blisters and a reddish colour at the base. Fruits with calcium deficiency have blackish spots internally with a gelatinous appearance. Kanapathy (1959) found that with calcium deficiency leaves were soft, flat and dark green and fruits were tasteless.

Excess calcium resulted in partially chlorotic plants with stunted growth (Collins, 1960), as it inhibits absorption of iron.

Magnesium

Magnesium is an important component of chlorophyll, green-colouring substance of the leaf, and is absolutely essential for any green plant. Though Mg requirement of pineapple is not large, its deficiency leads to restricted formation of chlorophyll, causing reduction in photo-assimilates. Besides, Mg is required for activation of several enzymes involved in photosynthesis and respiration.

Unlike calcium, magnesium accumulates more in leaves than in stem (Sideris and Young, 1946). Magnesium plays an important role in increasing average fruit weight as well as yield (Martin-Prevel, 1961). According to Moulinier (quoted by Py *et al.*, 1957a), magnesium fertilizers are often applied in Hawaii in relation to the potassium for maintaining ratio of K : Mg at 5 : 1.

Chlorosis becomes evident first in older leaves with magnesium deficiency as it is mobile. Under severe deficiency, yellow mottling appears, which at times coalesces to form an almost yellow stripe along the leaf margin; and leaves have a reddish tinge (Cibes and Samuels, 1958). Kanapathy (1959) noted pale-greenish yellow leaves. Fruits were sour without firm flesh with Mg deficiency. Plant with Mg deficiency have poor root anchorage (Glennie, 1977).

Sulphur

Sulphur, being a constituent of some amino acids and all proteins, is very much needed for plants. Its requirements by the pineapple-plant are as high as that of the phosphorus (Teiwes and Gruneberg, 1963). The deficiency of sulphur is a rare occurrence since sufficient quantities of this nutrient reach the soil as constituent of fertilizers such as ammonium sulphate, superphosphate as well as sulphate of potash. In addition, sufficient quantity of sulphur is carried by rains from the atmosphere to soil; especially in the industrial areas.

In the early stages of sulphur deficiency, leaves show very little change in appearance except for some blistering on older leaves. As deficiency advances, leaves turn lighter green, as happens in mild N deficiency. Fruits produced from S-deficient plants of Red Spanish variety exhibit abnormalities in structure and ripening. Unlike normal fruits, which ripen from base to top, S-deficient fruits ripen from top to base. A vacuole is also observed inside the fruit at the junction of ripe and unripe portions (Cibes and Samuels, 1958). Plant and fruit growth and slip and sucker production remain normal, excepting of the above mentioned fruit-development abnormalities (Cibes and Samuels, 1961). Of all the elements, sulphur deficiency has very little effect on yield.

MICRONUTRIENTS

On the basis of the frequency with which typical symptoms of deficiency occur in pineapple, iron can be regarded as one of the most important micronutrients, followed by zinc, copper, boron and manganese.

Iron

Iron, being a constituent of several enzymes, plays an important role as redox catalyst, participating in oxidation of carbohydrates and in reduction of sulphates and nitrates (Sanford *et al.*, 1954). Though iron is not a component of chlorophyll, its deficiency leads to reduced synthesis of the pigment.

Iron availability is very much limited in calcareous soils and in soils with high pH. Not only chlorophyll content but also protein content diminishes with iron deficiency (Sideris, 1948). Fresh weight of plant as well as fruit decreased in the absence of iron. The absorption and translocation of iron hinders within the plant with the presence of phosphates (Sideris and Young, 1956). Excess of manganese was found to induce iron deficiency (Hastie, 1959). Calcium chlorosis (Malan, 1954) occurring in pineapple in calcareous soils is on account of lime-induced iron deficiency.

The typical symptom of iron deficiency is chlorosis, disappearance of green, leaf-colouring substance, which also occurs with N deficiency. Chlorosis caused by iron deficiency appears on younger leaves in rosette (Sideris, 1955), and the one caused by N deficiency occurs first in older leaves (Py *et al.*, 1957a). In nitrogen deficiency, leaves formed before and during the period of deficiency become chlorotic in varying degrees. In iron deficiency, only the leaves which are formed during the deficiency period become chlorotic, while those formed before this period remain relatively green (Sideris and Young, 1956). Though mild N and Fe deficiencies are similar in appearance, the Fe deficiency normally differs from N with the presence of reddish tinge on the whole leaf (Cibes and Samuels, 1958).

Spraying Fe-deficient plants with a 3% solution of ferrous sulphate is a common practice in Queensland (Hastie, 1959). In Hawaii and Puerto Rico, regular spraying of ferrous sulphate forms part of the fertilizer programme of many plantations (Py *et al.*, 1957 a). In Hawaii, young plants are sprayed with ferrous sulphate at intervals of 14 days, whereas old plants are sprayed at monthly intervals (Collins, 1960).

Zinc

Zinc is required for synthesis of tryptophan, which is a precursor for indole acetic acid (IAA) synthesis. It is involved in the activation of several enzymes such as alcohol dehydrogenase, lactic acid dehydrogenase, glutamic dehydrogenase and carbonic anhydrase.

Zinc deficiency is often found in peaty and sandy soils which have high leaching rate or are strongly acidic with low pH (Aldridge, 1960). It can also occur on well-drained soils with a low humus content, if these soils have been strongly leached.

Smaller or larger transparent yellow spots on the leaf-lamina are characteristic of zinc deficiency (Tisseau, 1959). First symptoms of zinc deficiency are curling and twisting of leaves inside the rosette. Later leaves become narrow, acquire light green to yellow colour and their surface is covered with a thick layer of wax (Aldridge, 1960). In acute

deficiency, inner twisted leaves bend horizontally and downwards in bundles, giving plant a resemblance with a calabash fruit. This deformation is named as Crook-neck disease and is caused by a physiological disturbance due to zinc deficiency. Another characteristic of zinc deficiency is its occurrence in scattered spots in the field—in which apparently healthy plants stand directly along the side of the deficient plants (Dunsmore, 1957). Rehm (1956) observed chlorosis in Swaziland (South Africa) without any leaf curling.

Tisseau (1959) recommended a foliar spray of 1% zinc sulphate solution for correcting Crook-neck in Guinea. A spray solution of 2,000 litres is sufficient for treatment of plants in one hectare, i.e. 20 kg of zinc sulphate per hectare. With very acute zinc deficiency, spraying should be repeated. Zinc solution at 2 ppm improved fruit quality and 3 ppm was found to promote root growth (Srivastava, 1969).

Copper

High concentration of copper to an extent of 70% occurs in leaf-chloroplast. Copper activates several enzymes, viz. tyrosinase, cytochrome oxidase, polyphenol oxidase, ascorbic acid oxidase and phenolases.

Crook-neck disease is often identified with copper deficiency (Aldridge, 1960; Tisseau, 1959). A physiological disturbance called green die-back was found in Malaya due to copper deficiency alone (Teiwes and Gruneberg, 1963). It is characterized by leaves, which are thinner and narrower than those of healthy plants. Younger leaves of Cu-deficient plants are shorter and narrower. Severe copper deficiency causes death of plants.

Copper sulphate should not be applied as spray to leaves since it causes severe leaf scorching (Tisseau, 1959; Srivastava, 1969). Spraying the ground in the neighbourhood of the plants with 1.5–2.0% solution is recommended; 30-50 ml of the solution is distributed at a distance of 3–5 cm from the base of the plant (Tisseau, 1959). Since copper sulphate has a strong corrosive action, the use of metallic vessels should be avoided as far as possible. In replanting plots on which Crook-neck has already occurred, a preventive soil treatment should be carried out by mixing 25–40 kg of copper sulphate with fertilizers to be applied per hectare as a basal dressing. Annual dressings of 6–11 kg/ha are recommended along with fertilizer mixture to avoid green die-back in Malaya.

Boron

Boron acts as a regulator of permeability of plasma and promotes absorption of cations, but represses absorption of anions. Deficiency of

boron leads to collapse of conducting vessels such as cambium and phloem, which serve for transport of photoassimilates from leaf to storage organs. Cambium and phloem suffer to a greater extent than xylem vessels; conducting water and nutrients. The consequence of inadequate boron supply is accumulation of products of assimilation, reducing sugars and soluble nitrogen compounds, in leaves.

No visual symptoms on leaves are seen due to boron deficiency. However, there is a visible influence on fruit production; as fruits produced are abnormal in size and shape. The fruit is also small with pronounced separation and cracking of fruitlets. The cracks between fruitlets are filled with gum (Cibes and Samuels, 1958). Glennie (1977) reported brown corky flecks in inter-fruitlet areas. In severe cases, plants produce corky cricket-ball-size fruits or no fruits.

NUTRIENT INTERACTIONS

It is a well-known fact that a nutrient applied will not only result in increased content of the same in the plant, but will also bring about changes in the contents of other nutrients. This phenomenon is called nutrient interaction. A nutrient can have a favourable or depressing effect on other nutrients. Hence, application of other nutrients have to be monitored in relation to their interactions with nutrients applied. In view of the overlapping and opposite roles of nutrients, their optimal proportions are of more importance than their absolute quantities for successful pineapple production, particularly of the 3 most important cations, viz. potassium, calcium and magnesium.

NH_4 ions as well as K ions have an unfavourable influence on absorption of Ca and Mg. Scharrer and Jung (1955 a, b) on the basis of the influence of nutrition over the proportion of cations and anions in the plant concluded that the proportion is always constant, that is, no more cations are absorbed than the equivalent quantity of anions that are absorbed or formed (organic acids) by the plant due to the existence of the phenomenon called base-equilibrium constancy in every plant system. Therefore, higher concentrations of potassium led to a reduction in absorption of Ca and Mg (Sideris and Young, 1945) in pineapple. If nitrogen is supplied in the form of ammonium salt as cation, then proportion of anions to cations in nutrient solution is displaced. In contrast to other cations, ammonium ions decisively influence absorption of anions (Scharrer and Jung, 1955 b). The increased phosphate content (Sideris and Young, 1945) and greater acidity of pineapple-plants nourished with ammonium are explained by this. The tendency for adjustment to constant values of cations: anions is also present in the

absorption of ammonium (Scharrer and Jung, 1955 b). With ammonium (NH_4) nutrition, quantities of Ca and Mg absorbed by the plant must, therefore, be less than with nitrate nutrition; as is confirmed by Sideris and Young (1946).

Experiments were carried out by Martin-Prevel from 1956 to 1959 in Guinea to study influence of potassium, magnesium and calcium on the yield and quality of pineapple and in determining optimum fertilizer formula for these 3 cations. These cations influence yield and its factors and quality of fruits.

Yield and Yield Factors

Influence of cations on flowering. When acetylene treatment was given for flower induction in pineapple, largest number of plants were observed with cation proportions of 42.5 – 50% K + 42.5 – 50 % Mg + 0 – 15% Ca and the least with 0 – 25% K + 25 – 50% Mg and 50% Ca. All combinations of cations in which sum of K + Mg amounted to less than 85% led to a reduction of effectiveness of acetylene treatment. In younger plants, higher Mg and certain Ca content favour flower formation, whereas in older ones, a larger proportion of potash is necessary for flower formation (Martin-Prevel, 1961 a). Py (1959) did not observe any response of potassium and phosphate on effectiveness of flowering.

Influence of K : Mg : Ca on fruit weight and yield. According to Martin-Prevel (1961 a), the average weight of fruit and gross yield per hectare increased with higher applications of K + Mg + Ca. An application of 0.5 g equivalent of cations per plant with proportion of K : Mg : Ca at 42.5 : 42.5 : 15 and 50 : 50 : 0 and at constant rates of application of nitrogen and phosphate (5.5 g N and 3 g P_2O_5 per plant for the entire cycle) gave fruits averaging 1.525 kg and over, with a highest gross yield of 43 tonnes/ hectare. However, average fruit weight and yields obtained were not less even with K : Mg : Ca = 15 : 70 : 15 and 25 : 50 : 25. These figures show clearly that magnesium plays a very important part in getting higher yields, though significant increases are expected even with dominance of potassium. Too heavy dressings of calcium reduce average weight of fruit as well as yield. The optimum percentage proportion of cations was reported as 42.5 : 42.5 : 15 of K : Mg : Ca.

Effect on the duration of fruit development. It has been found that the period between acetylene treatment and ripening of the fruit decreased with increasing application of cations (Martin-Prevel, 1961 a). While fruits from unmanured plants could be harvested 190 days after acetylene treatment, it took only 175 days with dressings of 0.75 g equivalent of K + Mg + Ca. Alterations in K : Mg : Ca ratio influenced time of ripening.

Higher potash enhanced ripening while magnesium and calcium retarded it; and Ca seems to have a greater retarding effect than Mg. The optimum requirements are 70% K + 15% Mg + 15% Ca or 50% K + 50% Mg + 0% Ca.

Effect on the strength of fruit-stalk. A distinct relationship exists between the number of fruits standing erect, and the quantity of cations applied and the proportion of the cations (Martin-Prevel, 1961 a). The higher the proportion of potash and larger the supply of cations, the lesser did the fruit tend to fall over in spite of the higher fruit weight. With higher potash, the diameter of the fruit-stalk increased to a greater extent than the average weight of the fruit. The length of the fruit-stalk also increases with the level of potash application, resulting in no influence on stability. Calcium ions, if their share is more than 15% of the total cations, have an unfavourable effect on properties of stability, diameter and length of the fruit-stalk. Magnesium seems to affect stability of fruit-stalk to a lesser extent than calcium. Stability and diameter of fruit-stalk were almost same at K : Mg : Ca at 70 : 15 : 15, 50 : 50 : 0 or 42.5 : 42.5 : 15, but they were less when Mg increased at the expense of K.

Quality Characteristics

Colouration of fruit. Intensity of colouration of the fruit-skin increases with increasing application of potash (Py *et al.*, 1956). Martin-Prevel (1961 b) confirmed this, besides describing the influence of magnesium and calcium. A higher proportion of magnesium with the same potash resulted in a more intense colouration than a higher proportion of calcium. The occurrence of red and brown pigmentation on fruit-skin is linked with cation nutrition of pineapple. The red pigmentation which imparts desired colour to fruits is more with higher applications of potash. The accumulation of brown pigments around fruitlets, which imparts unattractive appearance to fruit, is more with higher calcium.

Effect on the core of the fruit. The core (central cylinder) must have a diameter as small as possible in order to obtain a larger fruit-flesh. With higher application of potash, it is expected to have an increase in the diameter of the core like that of the fruit-stalk, since morphologically core is a continuation of the fruit-stalk. However, it did not occur. On the other hand, Martin-Prevel (1961 b) observed thickening of core when calcium was dominating over magnesium.

Effect on the texture of fruit-flesh. The texture of the fruit-flesh was fibrous in plants which were given only nitrogen and phosphate. Plants which received generous Ca than K and Mg, produced fruits with least fibre content (Martin-Prevel, 1961 b).

Effect on juice content. Juice content increases with increasing

application of cations; potassium and to a smaller extent magnesium were the effective cations (Martin-Prevel, 1961 b).

Effect on acidity and sugars. The acidity of the fruit juice reduced with Ca and Mg, and increased with higher K applications (Martin-Prevel, 1961 b). Sugar content of the fruits does not increase significantly with the levels of K dressings, but acidity of the fruit juice certainly increases, resulting in reduction in sugar to acid content (Py *et al.*, 1956, 1957a; Su, 1958, 1959).

Effect on aroma and taste. Fruits derived from plants that had been treated with a fertilizer mixture in which potassium was predominant were superior with respect to aroma and taste. Magnesium also slightly favoured aroma and taste but calcium was found injurious (Martin-Prevel, 1961 b).

In overall analysis, maintenance of an optimum proportion of nutrients, especially cations K : Mg : Ca is a pre-requisite for higher yield of quality fruits. Though high yield and good quality is difficult to combine with one another, it is possible in pineapple to do so, since both yield and quality of the fruit are promoted by higher proportion of potash in the cation mixture.

Finally, it can be concluded that optimum quality can be obtained with 42.5% K, 42.5% Mg and 15% Ca.

NUTRIENT REMOVAL

Pineapple removes very large amounts of soil nutrients. Repeated cultivation on the same plots leads to severe reduction in yield after a few years, as a consequence of the great exhaustion of the nutrient reserves of the soil. Hence, heavy dressings with fertilizers are inevitable to maintain productivity.

Total quantity of nutrients removed by a pineapple-crop from the soil is obtained from an analysis of the plant drymatter, by determining

Table 6. Nutrients removed by pineapple (kg/ha)

Authors	N	P_2O_5	K_2O	CaO	MgO	Remarks
Stewart *et al.*	67	19	238	–	–	Yield 81 tonnes/ha
Krauss (1928)	350	121	1,131	245	–	18,375 plants/ha
Follet-Smith and Bourne (1936)	107	87	417	113	74	25,000 plants/ha
Boname (1920)	83	28	437	–	–	12,500 plants/ha
Cowie (1951)	123	33.5	308	–	–	100 tonnes/ha
Martin-Prevel *et al.* (1961c)	67.5	24.5	174	27	16.2	38,500 plants/ha with 55 tonnes/ha fruit yield

the nutrient contents of the plant substance analysed and the weight of the plant material produced per unit area (Table 6).

The nutrient uptake depends on the variety grown and is influenced by environmental and cultural factors such as soil, climate, planting density, fertilization and yield.

Relative Quantities of Nutrients

Pineapple has a high demand for nitrogen and potash. However, phosphorus is absorbed by the plant in relatively small amounts.

The removal of N : P_2O_5 and K_2O, has been calculated by Teiwes and Gruneberg (1963) (Table 7).

Table 7. Nutrient removal proportions of pineapple calculated from reports of different authors

Authors	N	:	P_2O_5	:	K_2O
Stewart *et al.*	1	:	0.28	:	3.5
Krauss (1928)	1	:	0.35	:	3.2
Follet-Smith and Bourne (1936)	1	:	0.81	:	3.9
Boname (1920)	1	:	0.34	:	5.3
Cowie (1951)	1	:	0.27	:	2.5
Martin-Prevel *et al.* (1961c)	1	:	0.36	:	2.6
Mean	1	:	0.40	:	3.5

The proportion of N : P_2O_5 : K_2O was calculated based on removal figures. The proportion on an average amounted to 1 : 0.40 : 3.5. The ratio of nitrogen to potash in nutrient removal by the plant is very wide. The amount of nutrients removed per tonne of fruits harvested was 0.75–0.80 kg nitrogen (N), 0.15 kg phosphorus (P_2O_5); 2.0–2.6 kg potassium (K_2O), 0.15–0.20 kg lime (CaO) and 0.13–0.18 kg magnesium (MgO) (Martin-Prevel *et al.*, 1962; Aldrigo, 1966: Black and Page, 1969; Lacoeuilhe, 1976). It shows importance of potash to pineapple for its successful growing.

Stages of Nutrient Requirement

In addition to the levels of nutrients removal, the course of nutrient absorption gives valuable information for fertilizer application. Studies carried out by Krauss (1928) as well as Follet-Smith and Bourne (1936) showed that pineapple accumulated highest amounts of N, P_2O_5 and K_2O at twenty-first month after planting. Nitrogen requirement was evident from the early growth stage and increased steeply from the sixth month onwards to fifteenth month; thereafter the requirement was

relatively less. Phosphorus requirement was almost same during all stages of growth, and it remained considerably less than nitrogen at any stage. Rapid increase in potash requirement was observed right from the third month to the twenty-first month, with a lag between the ninth and twelfth month.

The proportion of N : P_2O_5 : K_2O : CaO : S in suckers amounted to 1 : 0.21 : 1. 85 : 0. 65 : 0.15 and in developing plants (six months after planting) to 1 : 0.26 : 2.9 : 0.5 : 0.16 (Krauss, 1928).

LEAF ANALYSIS

Fertilizer is one of the major inputs, accounting towards higher cost of cultivation. With increasing cost of fertilizers, it is imperative to use them more efficiently and judiciously, not only to obtain higher yields per unit of fertilizer inputs, but also to avoid problems of environmental pollution due to their considerable build up in soil and accumulation in drinking water. It is in this context that leaf analysis has proved very useful in monitoring required nutrient status of pineapple at different stages of growth, and this is being widely used in crop-logging technique in Hawaii and Australia. Nutritional status of the plant as revealed by leaf analysis, which is carried out 2-5 months after planting, is the current basis for evolving individual fertilizer programmes for each plantation.

Leaf Sampling

The application of leaf analysis is largely dependent on the type of tissues sampled. Irrespective of the type of sample used i.e. the middle-third of the non-chlorophyllous part (Hawaiian technique) or the whole leaf (IRFA technique- Research Institute for Fruits and Citrus Fruits, Montpellier, France), the 'D' leaf is always used, as it is the only leaf that can be easily identified and that provides a reliable and sensitive indication of plant nutritional status (Py *et al.*, 1987). The 'D' leaf can also be used to estimate growth which is indispensable for interpretation of leaf analysis. In India, basal white portion (devoid of chlorophyll) of the 'D' leaf is generally employed for depicting nutrient status of pineapple at a given time more meaningfully in relation to yield. The 'D' leaf is defined as the most recently-matured leaf with maximum physiological activity. The vigour and nutrient contents of these leaves have been found to be highly correlated with growth and yield potential of pineapple-crop (Sideris and Krauss, 1938).

The 'D' leaves are sampled during vegetative growth only. Leaves can be sampled once the plant or sucker is large enough, and can be

tested until flower emergence. After flowering, plant has only mature leaves which are not suitable for analysis.

Sampling is usually done shortly before foliar sprays are applied, when levels are likely to be the lowest, and previous sprays have had sufficient time to be absorbed. Sampling has to be done at least 2 weeks after fertilizer application.

Identification of 'D' Leaf

In an actively growing plant, the A, B and C leaves are older than 'D' leaf, and 'E' leaves are comparatively younger (Fig. 11). The 'D' leaf is usually the longest leaf and is easily selected by gathering upper leaves in both hands. There are generally 2 and 3 leaves of similar length.

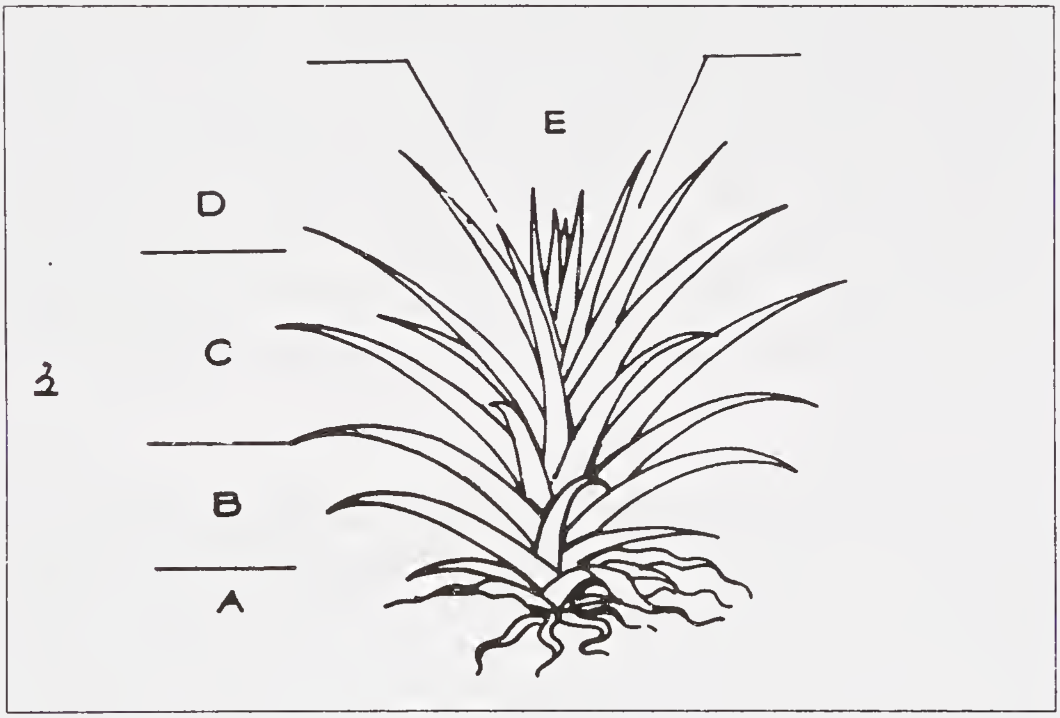

Fig. 11. Classification of leaves according to age

The 'D' leaf is removed by holding leaf in hand and giving leaf a sharp twist to one side and back to other side. The leaf should break out clearly with a sharp cracking sound. If it is difficult to remove then the leaf selected is probably too old and fibrous at the base.

Other ways of identifying 'D' leaf are by the shape of the leaf base, the amount of the basal white tissue and the absence of fibres (Fig. 12).

The white tissue of leaf flares out below the green tissue and curves slightly at the base. Younger leaves have a longer white section which does not flare out; is often tapering. Older leaves flare out considerably, have a shorter white section, and often fibres are visible at the base which make removal difficult.

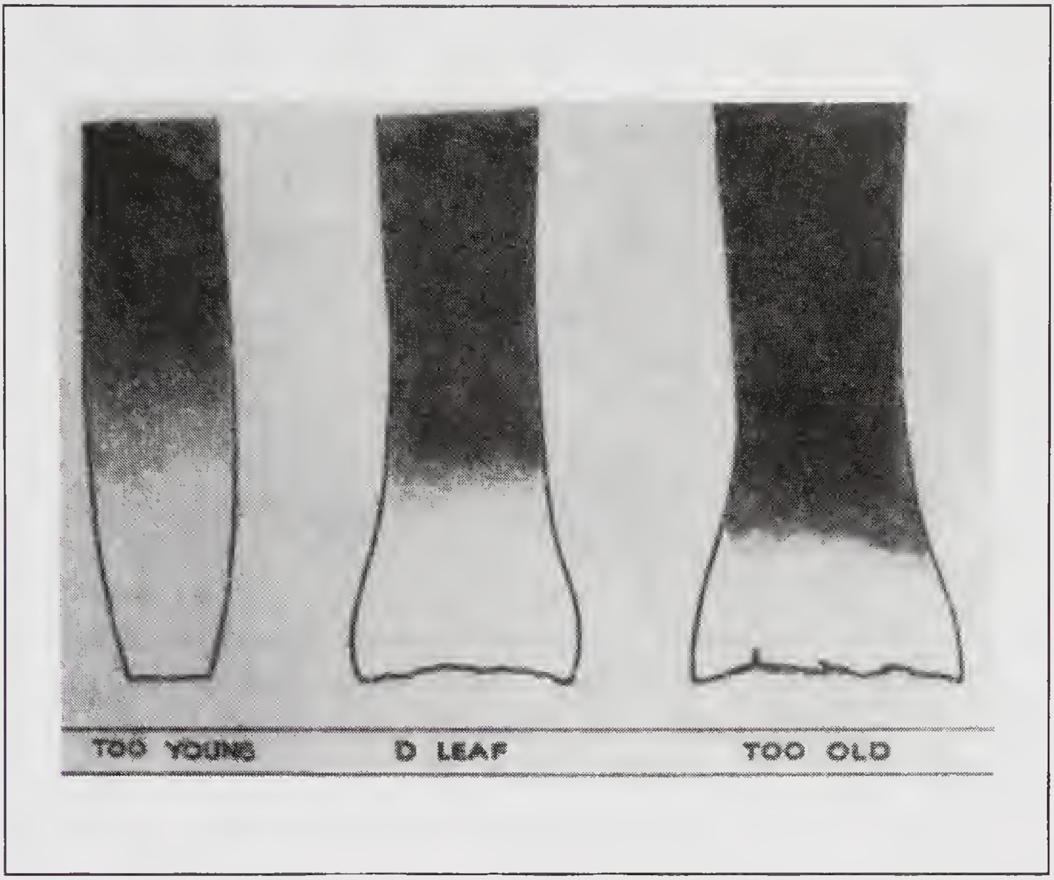

Fig. 12. Characterization of 'D' leaf

Leaf Nutrient Standards

In Hawaii, the highest yields and fruits of best quality were obtained when K : P ratio in the base of the 'D' leaf amounted to 12 : 1 (Cooke, 1949). Higher yields in Red Spanish Pineapple at Puerto Rico were obtained when leaf N, P and K were 1.66%, 0.14% and 4.25% (Samuels *et al.*, 1954); and there was no significant yield increases beyond these limits. In Taiwan, Pan (1957) found normal leaf nutrient values to be 1.5–2.0% N, 0.7–0.8% P and 3.5–4.0% K; in Puerto Rico, De Geus (1973) reported optimum leaf nutrient levels (% drymatter) for 2 cultivars by analysing basal part of the D-leaf as 1.7–2.2% N, 0.20–0.22% P and 3.5–4.0% K for Red Spanish cultivar and 1.6–1.9% N, 0.16–0.20% P and 1.8–2.5% K for Smooth Cayenne. Much lower figures were found in Ghana for cv. Sugarloaf. They were 0.35–0.40% for N; 0.04% for P and 0.44% K (De Geus, 1973). This shows that cultivars do exert some influence with regard to their nutrient requirement. The sufficiency requirement established for Smooth Cayenne from South Africa was 1.50%–1.70% N; 0.09–0.12% P; 2.20–3.00% K; 0.40–1.00% Ca and 0.30–0.50% Mg (Langenegger and Smith, 1978).

In peninsular India, a close correlation of N and K contents of the middle one-third portion of the D-leaf base of Kew pineapple, sampled

Table 8. Suggested leaf nutrient guides for pineapple from different places

Variety	Place	Stage (months after planting)	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	Authors
Red Spanish	Puerto Rico	–	1.66	0.14	4.25	–	–	Samuels *et al.* (1954)
	Taiwan	–	1.5–2.0	0.7–0.8	3.5–4.0	–	–	Pan (1957)
Red Spanish	Puerto Rico	–	1.7–2.2	0.20–0.22	3.5–4.0	–	–	De Geus (1973)
Smooth Cayenne	Puerto Rico	–	1.6–1.9	0.16–0.20	1.8–2.5	–	–	De Geus (1973)
Smooth Cayenne	South Africa	–	1.5–1.7	0.09–0.12	2.2–3.0	0.4–1.0	0.3–0.5	Langenegger and Smith (1978)
Sugarloaf	Ghana	–	0.35–0.40	0.04	0.44	–	–	De Geus (1973)
Kew	India	Fifth month	1.4	–	3.7	–	–	Subramanian *et al.* (1974)
Kew	India	Fifth month	1.51	–	–	–	–	Hariprakasa Rao *et al.* (1976)
		Eighth month	1.23	–	–	–	–	Rao *et al.* (1977)
		Eleventh month	1.97	–	–	–	–	
Queen	India	Eleventh month	1.04	0.16	–	–	–	Subramanian *et al.* (1976)

at the fifth month of plant growth, was found to exist with fruit yield (Subramanian *et al.*, 1972). It was observed that nitrogen content of 1.4% and potassium content of 3.7% on dry weight basis in the middle one-third portion of the leaf-base sampled in the fifth/sixth month could account for 90-95% of the yield (Subramanian *et al.*, 1974). This can be utilized in increasing productivity. If N and K are lower than mentioned above, the nutrient status of the plant could be effectively built up for yield increase. In Queen pineapple, nutrient status at eleventh month was better correlated with yield than at seventh month. The critical levels of N and P for basal leaf at eleventh month were 1.04% and 0.16% (Subramanian *et al.*, 1976). Based on the analyses, the critical levels of nitrogen in the middle one-third of the basal leaf base (base N) sampled at fifth, eighth, and eleventh months of plant growth were found to be 1.5%, 1.23% and 1.97%. Whereas in the remainder of the D-leaf at fifth, eight and eleventh months, the critical N levels were 0.99%, 0.81% and 1.37% (Hariprakasa Rao *et al.*, 1977). Since it is advisable to take up leaf analysis at an early stage of plant growth, to build up nutrient status of the plant for higher yields through fertilization, sampling at fifth month appears to be more appropriate. Suggested leaf nutrient guides for pineapple from different places are given in Table 8

9

Fertilizer Recommendations

FERTILIZATION practices such as the time of application and form of fertilizer can play a vital role in the efficient use of the applied nutrients, and this can result in the economy in manuring of pineapple.

The fertilizer practices recommended/prevailing in various parts of the world, based on the crop-removal studies of fertilizer experiments carried out to determine needs, are detailed as follows.

In Hawaii, the total amount of nitrogen required during growing period varied between 440 and 670 kg N/ha with plant stand of 39,500–43,000. The level of potash dressing amounted to 220-460 kg K/ha and that of phosphate to 170-280 kg of P_2O_5/ha (Collins, 1960). Cooke (1949) recommended fertilizer application at 9–12 months after planting, if fertility level at the time of planting is adequate.

A fertilizer dose of 120 kg N, 60 kg P_2O_5 and 120 kg K_2O per hectare was recommended in Brazil (Vasconcelos, 1952).

Py (1951) recommended application of a fertilizer mixture of ammonium sulphate (N), superphosphate (P) and sulphate of potash (K) in a ratio of 14 : 6 : 10; four times during a growing period at the rate of 120 g per plant for Puerto Rico and Cuba.

In Guinea, 15–20 g of ammonium sulphate, 4–5 g of superphosphate and 8.3–16.6 g of potassium sulphate/plant were applied in 3 instalments, viz. 2 to 3 weeks, 3 to 3½ months and 7 to 8½ months after planting (Philippe, 1960).

In the Ivory Coast, 4-2-11-2 g of N-P_2O_5-K_2O-MgO/plant were applied (cited by Samson, 1980).

Su (1957 a) recommended 560 kg N, 140 kg P_2O_5 and 560 kg K_2O/ha with a plant density of 36,000–42,000 in Taiwan. Nitrogen at the rate of 12 g/plant was found most suitable with regard to effectiveness and cost (Su, 1957 b). Pan (1957) recommended 3 : 1 : 5 ratio of N : P_2O_5 : K_2O for growing season and 5 : 1 : 3 for fruiting period in Taiwan.

In Queensland (Australia), Cannon (1960 a) recommended a basal dressing of 224 kg/ha of superphosphate and 840 kg/ha of potassium sulphate or a mixed fertilizer @ 1,200 kg/ha, containing 0-4-37% of N-P_2O_5-K_2O, specially formulated for basal fertilizer treatment. The quantities of P_2O_5 and K_2O supplied to soil through this fertilizer dressing were sufficient for first (plant crop) and second harvest (ratoon crop). Requirement of nitrogen was met by spraying 10% urea solution at

intervals of 2 months. The solution required per hectare was 360 litres when plants were young and increased to 540 litres for fully grown plants. The biuret content of urea should not be more than 0.25%. According to Glennie (1977), on a very deficient soil type, up to 600 kg N/ha is needed till the red-bud stage of the plant, and up to 450 kg N/ha after the plant harvest in a crop cycle of one plant-crop and a ratoon-crop. The amounts of nutrients needed per hectare for basal and foliar applications have been worked out to be 100 kg P, 1,200 kg K, 350 kg Ca, 300 kg Mg, 15 kg Fe, 7 kg Zn, 7 kg Cu and 1-3 kg B. These are maximum quantities and the amounts of major elements, in particular, would have to be scaled down for planting on better soils. Soil and leaf analyses have to be carried out for actual amounts needed.

Nitrogen at the rate of 471.7 kg/ha was found optimum for Smooth Cayenne in Kenya; and above which there was no further economic increases in yield of the crop. An application of 118 kg N/ha for ratoon-crop has been recommended. The trials conducted in Kenya did not show any response to potassium and phosphorus (Waithaka and Puri, 1971). In south-western Nigeria, high yields of cv. Smooth Cayenne were obtained with N, P_2O_5 and K_2O at 200, 100 and 200 kg/ha (Obiefuna *et al.*, 1987).

RECOMMENDATIONS FOR INDIA

In India, Nambiar (1934) on the basis of experience in Malabar, recommended incorporation of 25–30 cartloads of farmyard manure or a corresponding quantity of compost per acre before planting. Sane (1935) recommended 37.32 kg of ammonium sulphate, 74.64 kg of potassium sulphate and 111.97 kg of superphosphate per acre for pineapple. Chowdhury (1947) advocated an application of 5-10 tonnes of well-rotten cowdung or oil-cake per acre before or at the time of planting, besides, 13.6–18.1 kg of a mixture of 10-6-10 (N-P_2O_5-K_2O) soon after planting and 22.6 kg of the same mixture twice or thrice during every year for every 1,000 plants.

Gandhi (1949) recommended only top-dressing with 1,587 kg of fish manure in 2 splits; first after 2 months and the second split, 5 months after planting. A total of 1,866 kg–2,575 kg of compost basally, followed by top-dressing with 45.3 kg of ammonium sulphate per acre of pinery grown in poor soils was recommended by Bhattacharya and Sarma (1949). Naik (1963) recommended 25-50 cartloads of well-rotten manure per acre in 1 or 2 applications within 6-12 months after planting.

Kew pineapple did not respond to phosphorus and potash but a nitrogen dose of 12 g/plant was optimum in Basti (Uttar Pradesh)

(Teaotia and Pandey, 1964). In Bangalore, a fertilizer dose of 16 : 0 : 2.5 g of N, P_2O_5 and K_2O applied in 4 equal splits, at quarterly intervals, was found to increase fruit yield without reducing quality of Kew pineapple grown with irrigation facility (Chadha *et al.*, 1972). Queen pineapple was also found to give maximum response to 16 g of nitrogen per plant applied in 4 quarterly split applications in irrigated areas of Bangalore (Chadha *et al.*, 1976). But in a separate trial, on the requirement of nitrogen and irrigation for Kew pineapple in Bangalore, a nitrogen dose of 12 g/plant applied in 6 splits at bimonthly intervals was found optimum (Rao *et al.*, 1974); indicating possibility of improving efficacy of nitrogenous fertilizers by increasing number of splits. For medium fertile soils of West Bengal, 10 g N, 5 g P_2O_5 and 10 g K_2O are recommended per year per plant (DOA, West Bengal, 1976). At Chethalli (Coorg), in high soil fertility and irrigated areas, nitrogen at 12 g/plant and for rainfed areas at 16 g/plant was found optimum. High requirement in rainfed areas indicates complementary effect of nitrogen and irrigation in pineapple production. Experiments carried out at the Indian Institute of Horticultural Research, Bangalore and Chethalli, Assam Agricultural University, Jorhat, and Kerala Agricultural University, Thrissur, on nitrogen requirement and methods of application under the All-India Co-ordinated Fruit Improvement Project have revealed that nitrogen at the rate of 12 g/plant applied to Kew pineapple is found ideal for high yields of quality fruits. Potash at the rate of 12 g/plant has been found optimum for irrigated as well as rainfed areas. No response to phosphorus application was observed in plant crop. However, in ratoon crop, 4 g P_2O_5 /plant increased fruit weight and yields (Reddy and Prakash, 1982; Mustaffa, 1989). For irrigated and rainfed ratoon crops of Kew pineapple, nitrogen at 10 g/plant was found ideal (Ganapathy *et al.*, 1978; Reddy and Prakash, 1982). Detailed investigations conducted at the Indian Institute of Horticultural Research and other centres engaged in pineapple research to determine nitrogen requirement for Kew pineapple on the unit area basis rather than single plant basis revealed that 600 kg N per hectare with a population density of 43,600–63,500 plants was optimum.

It is advisable to give N and K_2O at 12 g each per plant. There is no need for phosphorus application. However, if soils are poor in phosphorus, 4 g of P_2O_5 /plant can be applied. N should be applied in 6 split doses. The first dose of nitrogen can be given 2 months after planting and the last dose 12 months after planting. Potash should be given in 2 splits. Entire phosphorus and half the dose of potash can be given at the time of planting and the remaining potash 6 months after

planting. Application of fertilizer in rainfed areas has to be done when moisture is available.

Type of Fertilizers

The age-old practice of manuring pineapple was mostly restricted to burial of harvested plants after the end of the growing cycle and raising green-manuring crops between 2 successive growing cycles. These measures certainly help in maintaining humus status of the soil, but the quantities of nutrients they return to soil are relatively smaller to the requirement of pineapple-plants. Therefore, use of organic manures to pineapple growing will always be of less importance. Hernandez-Medina and Lugo-Lopez (1958) did considerable work in Puerto Rico on the effects of filter-press cake (by-product of sugar industry) alone and in combination with other fertilizers. Filter-press cake at 72 tonnes/ha plus an inorganic fertilizer 12-6-10 (NPK) at 1,680 kg/ha gave vigorous, dark-green plants; resulting in higher yields.

With the advent of awareness of inorganic fertilizers as useful sources of nutrients, more emphasis has been laid on such sources in manuring. The plant nutrients are supplied through soil not as pure elements but always as fertilizer-salts. The carrier substances contained in fertilizers, whether they are constituents of fertilizer-salts or impurities, exhibit some influence on growth of the plant. Therefore, application of different fertilizers with the same amount of nutrients can bring different effects on the growth, yield and quality of pineapple.

Nitrogen fertilizers. The sources of nitrogen largely available in the market as fertilizers are ammonium sulphate, ammonium nitrate, ammonium-sulphate nitrate, calcium-ammonium nitrate and urea. Ammonium sulphate is extensively used for pineapples. With regard to suitability of various types of nitrogenous fertilizers, ammonium nitrate was compared with ammonium sulphate on 2 different soils for Red Spanish pineapple by Pennock (1949) in Puerto Rico. Ammonium sulphate always gave a higher yield than ammonium nitrate. The chemical action of the ammonium sulphate is lowering of soil pH near the root zone, which is favourable for pineapple. In addition, nitrogen assimilation by pineapple was more when it was applied as ammoniacal form as compared to nitrate form (Sideris and Chun, 1947). Though pineapple can absorb and utilize nitrate ions as well as ammonium ions (Sideris *et al.*, 1939), ammonium sulphate proved itself superior to nitrate fertilizers in many experiments in Guinea and South Africa (Py, 1956, 1957a, 1957b; Oliver and Webster, 1969). Ammonium sulphate also excelled at to urea in producing favourable effects on plant growth and

fruit weight (Py, 1962; Oliver and Webster, 1969). Ammonium sulphate was also observed better than calcium-ammonium nitrate and urea for Kew pineapple (Chadha *et al.*, 1975; Khatua *et al.*, 1988). It resulted in higher fruit weight, yield and sucker production. Subramanian *et al.* (1974) attributed this to the complimentary effect of sulphur in the soils, which was comparatively more in the treatments where ammonium sulphate was added. In contrast to this, a trial conducted at Thika (Kenya) comparing ammonium sulphate, ammonium-sulphate nitrate and calcium-ammonium nitrate as sources of nitrogen did not show any differences in plant-crop yield (Waithaka and Puri, 1971). However, for ratoon-crop yield, ammonium-sulphate nitrate and calcium-ammonium nitrate were superior to ammonium sulphate.

Urea is widely used for foliar application and liquid manuring in pineapple.

Phosphatic fertilizers. The phosphatic fertilizer, mostly used, in many pineapple-growing regions is superphosphate. Samuels and Gandia Diaz (1963) observed that with the exception of diammonium phosphate, which significantly lowered total yields of the plant crop and ratoon crop, all other forms of phosphorus resulted in similar yields on the sandy clay soils of Puerto Rico.

Potassic fertilizers. Of the potassium sulphate and potassium chloride (KCl), which are available commercially, potassium sulphate (K_2SO_4) is ideal for growing pineapples. In some areas preference is given to potassium chloride due to its low cost and high K_2O content. The influence of chlorides on the metabolism of pineapple is evidenced by leaf necrosis, which is often observed on pineapple in coastal region. The necrosis is ascribed to chloride damage with simultaneous deficiency of potash (Sideris and Young, 1954). In Taiwan, potassium sulphate was found far superior to potassium chloride with regard to yield and quality as well as the profitability of fertilizer treatment (Su, 1958-59; Su and Li, 1962). On sandy-clay soils in Puerto Rico, pineapples fertilized with potassium sulphate gave a higher yield and fruit weight than plants fertilized with potassium chloride (Samuels and Gandia Diaz, 1960). Superiority of potassium sulphate over potassium chloride can be attributed to the favourable effects of SO_4 ions on soil pH and sulphur status of the soil. However, there was no difference between potassium sulphate and muriate of potash with regard to yield and quality of Kew pineapple in India (Chadha *et al.*, 1975). Similarly, Langenegger and Purdon (1977) observed little difference in yield between 2 sources of K, but potassium chloride was more economical. With spray applications, potassium sulphate gave better yields.

Methods of Fertilizer Application

Primarily there are 3 methods of fertilizer application in pineapple, viz. soil application, foliar application and liquid fertilization.

Soil application. It is most widely followed in India and other countries, where the use of paper or polyethylene mulch is not followed. In Cuba, studies on Red Spanish cultivar with 3 methods of application revealed that application of fertilizers in bands along the rows was economically more viable than applying fertilizers to axils of the lower leaves and foliar spray (Nunez Soto and Garcia Serrano, 1978). Experiments conducted at the Indian Institute of Horticultural Research have shown that application of part or full dose of nitrogen in the form of foliar spray of urea did not prove superior to nitrogen applied to soil alone (Reddy *et al.*, 1983).

Foliar application. This is a common practice in several countries such as Australia (Cannon, 1960; Mitchell and Nicholson, 1965), China (Su and Huang, 1956), French Guinea (Py, 1962), Hawaii and the Philippines, wherever mulching is a common practice. Leaf spraying is well adapted to pineapple morphology since trichomes play an important role in absorption of elements in solution (Sakai and Sanford, 1980). Experiments with ^{15}N (Marchal and Pinon, 1980) have shown higher absorption of nitrogen on the underside of leaf, which has more trichomes. The younger is the leaf and trichomes, the higher is the rate of absorption. First dose of fertilizer is applied before spreading mulching material and later doses of fertilizers are applied through foliage or liquid fertilization. In Kenya, a basal application of NPK to soil prior to spreading plastic mulch and foliar application of urea from fourth to fourteenth month was found to increase greatly total yield and also Grade I fruits (Waithaka and Puri, 1971). In pineapple, foliar application is of special importance due to spiny leaves and high-density plantations.

Liquid fertilization. In some plantations in Hawaii, ammonium sulphate and potassium sulphate are applied to axils of lower leaves in the form of a solution; in which a boom-type-sprayer is employed. Fertilizers reach leaf and soil in the form of solution and can be absorbed directly by the plant. Since fertilizers are applied in a considerable diluted form to avoid scorching of younger leaves, it also provides considerable quantities of water at the disposal of plants during dry seasons.

To sum up, soil application was found the best method of manuring pineapple. However, in places where use of polyethylene or plastic mulches is prevalent, supplementary manuring of nitrogen through foliar application of urea seems to be relevant.

10

Interculture

EARTHING UP

This is an essential operation in pineapple cultivation aimed at good anchorage to plants. It involves pushing soil into the trench from the ridge, where trench-planting is a common practice. As pineapple roots are shallow, plants lodge in heavy rainfall, especially in flat-bed plantations. Lodging of plants when fruits are developing on them would result in lopsided growth, uneven development and ripening of fruits. This operation becomes more important in ratoon crops as the base of the plants shifts up crop after crop (IIHR, Bangalore, 1977). Close planting with 63,000 plants/ha would minimize lodging as plants prop one another (Chadha *et al.*, 1974).

WEED CONTROL

Successful weed control is very important in pineapple growing. Hand-weeding is common in pineapple culture in India. In tropical areas, weeds grow profusely and hamper growth of pineapple-plants, especially during early stages of plant growth. Therefore, quite a number of weedings are necessary in a year to keep pinery free from weeds. The major factor which contributes to high cost of production of pineapple is the manual weeding; which accounts for nearly 40% of the total cost of production. A total of 130 tonnes/ha of weeds were collected in 3 manual weeding operations over the course of a year, during an experiment carried out in Cameroon (Gaillard, 1971). Pinon (1976) obtained mean yield of 14 tonnes/ha in unweeded plots, as compared to 79 tonnes/ha in manually weeded plots, and as opposed to 83 tonnes/ha in plots treated with chemical herbicide and with supplementary hand-weeding. The non-availability of labour and high wages during recent years have aggravated problem of pineapple cultivation and its extension to new areas.

Hand and mechanical weeding were used primarily until oil emulsion sprays were developed in 1940.

Soil-mulching also has been tried as means to check weed growth. In Hawaii, early attempts to control weed with paper, straw and polythene-film mulches were successful (Savage and Barnett, 1934; Collins, 1960). Paper mulch was found uneconomical in some areas (North-Coombes,

1941), and for achieving clean weeding, areas between beds need weed-control measures. Besides using mulches for weed control, the field lay-out has to be specific, and special machinery is required for this purpose.

The control of weeds with herbicides offers a good alternative to manual weeding, especially in pineapple-plants, as leaves are spiny, and may restrict movement of labourers under high-density plantations. Weeds must be controlled in pineapple by shallow weeding or by sprays, as deep cultivation would interfere with shallow-root system. Thus, chemical weed control has an added advantage here.

The first attempts at chemical weed control with 2, 4-D were unsuccessful as it was found to affect flowering adversely (Crafts and Emanuelli, 1948). During fifties, pre-emergence herbicides such as Manuron (CMU) were developed; and then selective materials for the control of weeds, those escape pre-emergence sprays, were used (Gowing and Lange, 1962). The next development in chemical weed control was Pentachlorophenate alone or in diesel oil emulsion, as early as 1951 in Queensland. Pentachlorophenol (PCP) (1.36 kg) and sodium pentachlorophenate and one gallon of mineral oil or creosote emulsion/ 100 gallons controlled broad-leaved weeds, but higher concentrations were needed for grasses (Cannon, 1952). The first good pre-emergence chemical for weed control was Manuron (CMU). Good control of weeds was obtained with 27–55 kg/ha of CMU as a pre-emergence ground spray (Wolf, 1953). Py (1955 b) obtained good results on Asteraceae with 2.5 kg (80% active) CMU/hectare. Cannon and Prodonoff (1959) found 4 lbs of CMU/acre to be better than 20 lb/acre of PCP. No injury to pineapple occurred with even up to 8 lb/acre of CMU, but 8 lbs gave no better control than 4 lbs. Diuron is an improvement over CMU. It is safe in rainy season; CMU can be used only during dry season (Barbier and Trupin, 1956). Diuron at 2.5–5.0 kg/ha seemed to be successful in controlling weeds (Py, 1959 b), provided grasses were destroyed before planting either mechanically or with Dalapon. Cannon (1960 b, 1960 c) found Diuron and Atrazine promising and superior to CMU, PCP and Simazine, whereas TCA and Dalapon were injurious even at 1.6 kg/ha. Effective weed control can be achieved by the use of more than one chemical. Guyot and Oliver (1958) found best results with 6 litres of PCP and 3 kg of Diuron in 52 litres of orchard spray-oil. In the Philippines, Manuel (1962) reported that CMU and Simazine at 2, 4 and 6 lbs in 30 gallons of water/acre gave satisfactory control in very dry areas. In Ivory Coast, Simazine plots (5 kg/acre) had the least number of weeds, 20 weeks after treatment. Diuron (80% active) at 25 kg/ha was almost as effective and even superior to CMU but PCP was not at all effective

(Silvey, 1962). Diuron and Manuron applied 12 days after planting pineapple at 2 kg/ha gave good control of weed flora, composed mainly of grasses (Rein, 1962). Reynhardt *et al.* (1967) obtained good weed control with Diuron or Manuron applied at 2 lb/acre every 4 months or at 1 lb/acre every 3 months. Out of the 32 herbicides tested, Dodson (1968) noticed good success in controlling weeds with Bromacil and Terbacil at rates often as low as 1.6 lb a.i./acre. Hyvar-X (Bromacil) at 4 kg/ha gave satisfactory control of weeds (Guyot, 1970). But Gaillard (1971) suggested Bromacil at the rate of 7.2 kg/ha at intervals of 4 months which gave good weed control, including nut-grass, and its effectiveness was related to the dose applied.

In India, extensive work was carried out at the Indian Institute of Horticultural Research, Hessaraghatta. The work revealed that weeds could be effectively and economically controlled (Fig. 13) by the application of Bromacil + Diuron at the rate of 2 kg/ha; each sprayed as the pre-emergence herbicide to weeds and as soon as the pineapple suckers were planted (Dhuria and Leela, 1971). In established pineapple plantations, weeds have to be removed before spray is given as both Bromacil and Diuron do not kill established weeds effectively. If pineapple fields are not infested with *Cynodon dactylon*, Bromacil alone at 3 kg/ha can be as effective as the combination of the two (Dhuria and Leela, 1971, 1972). If Bromacil is not available, Diuron at the rate of 4 kg/ha can be used. Experiments conducted at the Pineapple Research Station, Vellanikkara, Thrissur (Kerala), showed that Diuron at 3 kg/ha

Fig. 13. Weed control with herbicides (treated area in the background).

or a combination of Diuron at 1.5 kg/ha + Bromacil 2.0 kg/ha applied as pre-emergent spray and repeated with half of the dose, 5 months after the first application, was very effective in controlling weeds (AICFIP, 1978). Similarly, Diuron or Bromacil at 3 kg/ha or Diuron + Bromacil at 2 kg/ha each gave effective control of weeds at Jorhat (Assam) (AICFIP, 1978).

Quantity of Herbicide Solution to be Sprayed

The rate of application of herbicides must be uniform. Thousand litres of water containing 2 kg of each herbicide per hectare would be sufficient to give satisfactory spray coverage.

Application of Herbicides

It is convenient and effective to apply herbicides before planting propagules. If herbicides are to be applied after planting, keep spray nozzle facing towards soil; avoiding pineapple-plants as far as possible in order to minimize wastage of chemical. The herbicides at the recommended doses are not harmful, even if they fall on the plants. Irrigate 2–3 days after the spray, as sufficient moisture is necessary to carry herbicides to the root zone of the weeds. It takes 12–15 days for showing effect of herbicides on growing weeds. Sprayers used for herbicide application should not be used for spraying any other pesticide.

Duration of Weed Controı

Bromacil and Diuron work very effectively in sandy and clay-loam soils. Both broad-leaved and grassy weeds (including nut-grass and *Hariyali*) are controlled for one year and four months. In areas where density of weed flora is high, effect of herbicides may break down after one year, and then, a second spray consisting of half the concentration of the first spray, needs to be given.

Cost of Weedicide Application

As charges for hand weeding vary in different parts of the country, only the cost of weedicide application is given, which is as follows.

Year	Weeedicide	Total cost/ha (Rs)
First year	Weedcide @ 4 kg/ha* applied	800
	Labour charges for spraying (8 man-days)	200
Second year	Weedicide @ 2 kg/ha* applied	400
	Labour charges	200
Total		1,600

* cost of Durion taken at Rs 200 /kg

MULCHING

Mulching is one of the cultural practices aimed at weed control and soil-moisture conservation. It is very widely followed in Hawaii, Australia and Taiwan. It is essential when pineapple is grown as a rainfed crop and is feasible where flat-bed planting is followed. Before planting, fields are ploughed thoroughly, followed by discing to smoothen surface, providing a fine state of tilth. Smooth soil surface is essential to place mulching paper or other mulching materials. Fertilizers and soil fumigants are added to soil before placing mulching material.

In New South Wales, paper mulch was found beneficial in very dry seasons for maintaining higher top-soil moisture and allowing plants to feed on the top soil (Savage and Barnett, 1934). With this, flowering and fruit maturity occurred 2-3 weeks earlier, and yields and fruit quality were better than control, and weed problem was very much reduced. In a region with very low rainfall in Hawaii, Magistand *et al.* (1935) compared a mulch of bagasse (crushed sugarcane stalks) with paper mulch, the one commonly used. The yield and soil moisture were highest under bagasse mulch, and paper mulch improved nitrogen content of the soil and kept the soil warm, particularly in winters. Warm temperature in root zone is very favourable for pineapple. Covering ground with tarred paper raises soil temperature and prevents fields being infested with weeds, especially during the first twelve months after planting, before the leaves of the pineapple-plants shade ground sufficiently, besides preventing losses of N by leaching and water evaporation. The yields increased by 22–34 tonnes/ha with paper mulch. Plant nutrients, however, are not supplied by paper mulch, as is done by bagasse and other organic mulching materials. In Taiwan, Su *et al.* (1956-57) tested effect of rice-straw mulch on the soil, yield of the pineapple and quality of fruits. Mulching increased moisture content of the soil, amount of available potassium and nitrogen and the organic-matter content. N, P_2O_5 and particularly K in the leaves increased with increased applications of straw. If soil was mulched with rice-straw only between the rows, the yield stood at 33% above that of the control. All over mulching raised yield by 50%. The production of fresh sound fruits with firm tissues and high sugar content increased by 133%. In regions with a low rainfall in Hawaii, mulching with pineapple trash has been employed in combination with a paper mulch (Collins, 1960). The trash is produced by chopping and crushing old pineapple-plants which remain on the field at the end of the crop cycle, and placed over the soil surface, without the use of paper; or it may be placed between the papered beds, or both, on and between the papered beds. The most commonly used

method combines paper mulch on the beds and trash in spaces between beds. Trash mulch should not be used in regions with adequate or high rainfall, as it acts as a mediator in the spread of fungal diseases. Use of light weight paper mulch is commonly followed in Australia, which lasts for 15-18 months (Cann, 1961). Black polythene was found significantly superior to straw as a soil covering, for limiting water loss in dry season in Guinea (Py, 1965). Straw depressed vegetative growth, whereas polythene favoured, if not significantly, growth and yield.

Mulching is not a common practice in India. Use of dry leaves or straw is in practice in some areas of south India (Naik, 1963). Preliminary trials conducted at the Indian Institute of Horticultural Research, Bangalore, revealed that mulching with black polythene and saw-dust resulted in better growth of plants as compared to white polythene and paddy-straw mulching (Sharma *et al.*, 1971). Chadha *et al.* (1974) recommended high-density planting to minimize need of mulching.

Benefits accrued through paper mulch are as follows:

(a) It helps to keep soil friable and warm during cold weather;

(b) It reduces weeding costs since weeds cannot grow in darkness under paper;

(c) It conserves moisture especially of the surface layers of the soil where the roots of the young plants are developing. Conserved moisture ensures constant availability of nutrients present in the soil;

(d) It reduces leaching of soluble N and other nutrients;

(e) It results in vigorous and uniform growth of larger and healthier plants, earlier crop and better propagules;

(f) It ensures better quality fruit and higher yields (Collins, 1960; Cann, 1961).

Though paper mulch has been used with success for a number of years, it has now been largely replaced by black polythene film of 0.03-0.05 mm thickness, which lasts longer and has the same advantages (Samson, 1980).

REMOVAL OF SUCKERS, SLIPS AND CROWNS

Suckers start growing with the emergence of inflorescence and slips grow with developing fruits. As one or two suckers, depending on the plant density, need only to be retained on the plant for ratooning, additional suckers and all slips are removed; as the growth of these may weaken plant and hinder fruit development. Fruit weight was found to increase with increasing number of suckers per plant, while increased number of slips delayed fruit maturity. Crown size has no bearing on fruit weight or quality (Chadha *et al.*, 1977). Hence, desuckering can be

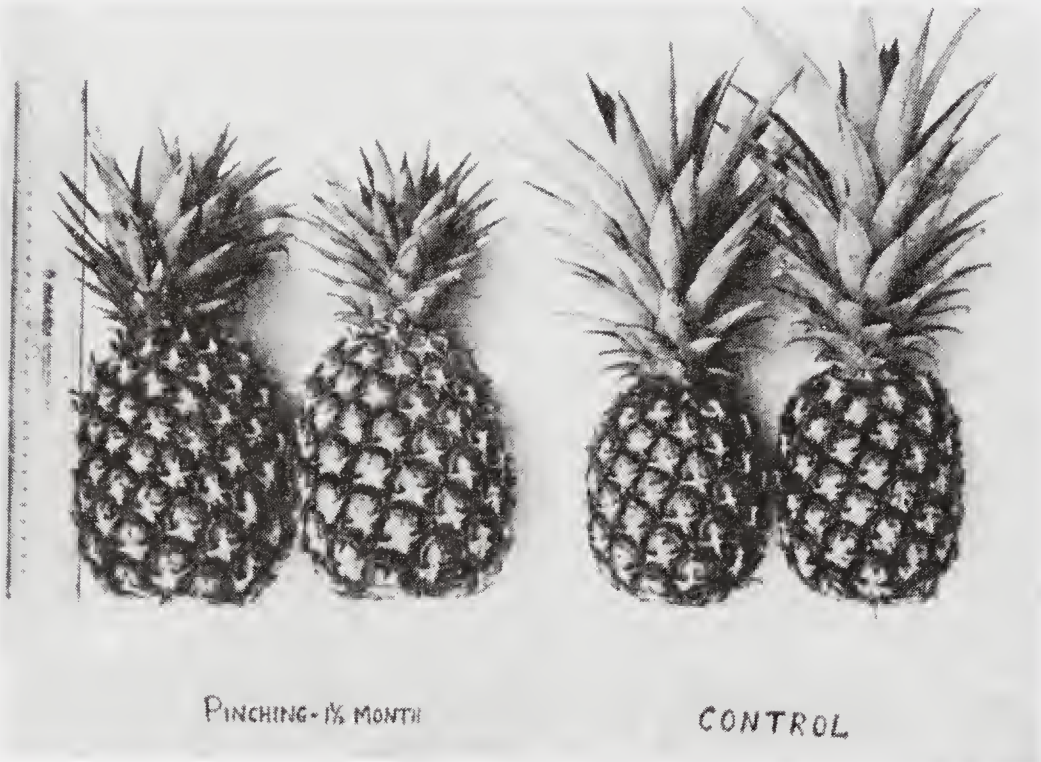

Fig. 14. Fruit size increases due to crown pinching

delayed as much as possible, while slips are recommended for removal as soon as they attain the size required for planting. In a situation where early harvest is required or slips are not required for planting, they can be removed as and when they sprout. Removal of crown is not required as it mars appeal of fruit and also makes handling difficult. However, reduction of crown size is necessary in Smooth Cayenne, if the fruits are intended for export. The meristem of the crown is gouged out with a chisel when it is about 8 cm long to restrict oversizing of crowns. One man can perform this operation on 1,000 to 2,000 plants per day (cited by Samson, 1980). Partial pinching of crown in Kew pineapple consisting of removal of the innermost whorl of leaflets along with the growing tips 1½ months after fruit set was found best to get better fruit size and shape (Prakash *et al.*, 1983; Fig. 14).

11
Irrigation

WATER REQUIREMENT

PINEAPPLE is grown mostly as a rainfed crop in heavy rainfall areas. Optimum range of rain needed for pineapple is 1,000 to 1,500 mm. However, some of the pineapple-growing areas come under high-rainfall zone, where rainfall is to an extent of 3,000 mm (in Cameroon and Costa Rica), between 2,600 and 2,900 mm (in Malaysia) and nearing 2,000 mm (in Taiwan). As pineapple roots are very sensitive to waterlogging, good drainage is necessary. Potential evaporation figures range from 1,472 mm in Malaysia to 839 mm in South Africa (Bartholomew and Kadzimin, 1977). A potential evapotranspiration of 3.5–4.5 mm/day was reported for Vamoussokro at 7°N latitude in Ivory Coast.

As such pineapple is a xerophyte, having many adaptations to drought. Its stomata close during day when much moisture can otherwise be lost. Its leaves have stiff and waxy upper surface and have stomata in furrows on the lower surface; protected by thick growth of hairs called trichomes, which minimize loss of water through transpiration. Leaves are also arranged in a rosette, very close to each other, on a condensed stem in such a way that rainwater collected gets conducted to the base and will hardly pass to the ground. Similarly, dew collected at the leaf bases is also absorbed. Thus, pineapple utilizes thoroughly the available water in the atmosphere and needs very little water through irrigation. Hence, Rao *et al.* (1977) termed pineapple 'A boon for dryland agriculture'. As water-holding capacity of the soil rarely surpasses 100 mm and potential evapotranspiration from the plant can go up to 4.5 mm per day, pineapple exhausts water supply in 3-4 rainless weeks (Samson, 1980). Under such conditions, even though the plant is drought resistant, but the dry conditions can lead to delayed growth and fruiting. Hence, supplementary irrigation in drier periods and in low rainfall areas is beneficial. As such irrigation is supposed to be a luxury for pineapple. A total of 14-22 tonnes of pineapples per hectare were harvested additionally with supplementary irrigations in Ivory Coast (Samson, 1980).

According to Sideris and Young (1945), pineapple-plants with an average weight of 4,287 g require 60,860 g of water from the commencement of growth to the time of blossom formation for transpiration

and development of plant substance alone having 42,500 plants/ha with 4.45 cm rainwater per square cm. In this, losses of water from soil by seepage and surface run-off or evaporation are not taken into account. In some places in Hawaii, where rainfall exceeds 2,540 mm (100 inches), it affects quality and keeping properties of fruit (Malan, 1954). In Hawaii, a rainfall of 1,100-1,300 mm (45-55 inches) is regarded as optimum (Cooke, 1949). Pineapple needs a well-distributed rainfall of about 1,200-1,500 mm annually (Giacomelli, 1967). Application of 120 mm water monthly in 4 doses has not been found superior to 60 mm, but both treatments significantly improved growth, flowering, yield and sucker production.

Although pineapple is grown in India in rainfed areas, where sufficient rainfall is received, but it can also be grown successfully with a few irrigations during summer in the semi-arid tropic regions of the country, where average rainfall varies between 1,000 and 1,200 mm annually, distributed fairly in the rainy season, as around Bangalore. A scientific approach towards finding out water requirement of pineapple was made by Rao *et al.* (1974) at the Indian Institute of Horticultural Research. As a result, it was observed that 80% depletion in the available soil moisture is as good as 20% depletion in the available soil moisture or in other words an available soil moisture regime of 100 - 20% was sufficient for Kew pineapple. Therefore, in scanty rainfall areas and years and during hot weather, irrigating pineapple once in 20-25 days is advisable wherever facilities are existing to ensure a good crop. Experiments conducted at Chethalli (Coorg) revealed that 4 irrigations during summer were desirable, which not only increased yield by 20 tonnes/ha but also advanced plant-crop cycle by 7-9 months by way of increased plant growth and advanced physiological maturity (Singh *et al.*, 1977). Irrigation can also be helpful to establish off-season planting to maintain year-round production of fruits for feeding canning factories.

Methods of Irrigation

There are 5 methods of irrigation in vogue. These are flat-bed irrigation, furrow irrigation, trench irrigation, sprinkler irrigation and drip irrigation.

Flat-bed irrigation. This is followed in areas where pineapple is planted in flat-beds and soil surface is even. Uneven distribution and wastage of water and concentrations of applied nutrients at one side of the field are drawbacks of this system.

Furrow irrigation. This system is practised in places where pineapple is planted in furrows and topography is of gentle slope. Water is let in from one end of the furrow to the other. Accumulation of applied

nutrients at the farther end of the furrow is the major problem.

Trench irrigation. This is similar to furrow irrigation except that water is let in between rows of the crop in a trench.

Sprinkler irrigation. This system is not very common in India, excepting in commercial pineries owned by canning industries. Though this involves high initial investment, it ensures efficient use of water. Moreover, it can be employed to irrigate in highly undulated terrain of land where conventional systems are not successful. Trials carried out elsewhere have revealed that sprinkler irrigation of pineapple fields in Taiwan during dry season at intervals of 2, 4 or 5 weeks significantly improved plant growth and weight of spring- and summer-maturing fruits in proportion to the frequency of irrigation (Huang and Lee, 1969). Low volume but frequent sprinkling of water by this system increases humidity of microclimate around plants which is highly desirable. The added advantage with sprinkler irrigation is that application of fertilizers and insecticides can be carried out along with irrigation.

Drip irrigation. It requires high initial investment. There is one pipe per row of plants, i.e., approximately 8,000 metres of pipe is needed to irrigate 55,000 to 60,000 plants/ha (Py *et al*., 1987). Since it is expensive, cost-effectiveness of this system depends on the regular inclusion of fertilizer and pesticide in the irrigation water and production of two or even more successive harvests. This system also has drawbacks as water has to be filtered and the flow needs to be controlled, depending on the slope of the ground.

Of late, bi-wall pipes are generally used for irrigation and are laid at the same time as the plastic mulch. In Hawaii, irrigation rate is constant at around 7 mm/week (Teisson, 1970). Other localized systems of irrigation through perforated pipes and microjets are not suited for pineapple cultivation.

12

Means to Improve Flowering and Fruit Quality

FLOWERING

ONE of the major impediments in successful cultivation of pineapple is its erratic flowering behaviour. Even after 15-18 months of growth under ideal management, less than 40-50% of the plants normally flower, leading to overlapping of operations and irregular supply of fruits to canning factories. Therefore, it is of utmost importance to regulate flowering for better returns as well as to have a regular supply to canneries. Regulation of flowering will also be beneficial in economizing labour requirement.

Pineapple, being native to tropics, shows almost no periodicity (Collins, 1960). The inference that all tropical plants are insensitive to day-length is incorrect (cited by Samson, 1980). Pineapple variety Smooth Cayenne is a quantitative short-day plant (Gowing, 1961; Py and Tisseau, 1965), and for its promotion of flowering it does not require either diurnal variation in temperature or temperature below 25°C (Friend and Lydon, 1979). Other cultivars react only weakly to day-length but may flower when temperature falls (Bourke, 1976). In Red Spanish cultivar, low temperatures were more effective in promoting floral initiation than reduced day-length (Van Overbeek and Cruzado, 1948). As low temperature usually coincides with short days, these effects are generally confused. When Cayenne plants are sufficiently big, floral initiation takes place closer to short days, and flowers appear 60 days later. Pineapple variety Kew, grown extensively in India, is akin to Smooth Cayenne. Natural flowering in Kew extends from December to February and harvest of fruits from May to July during rainy season. As a result, processing factories experience short supply of fruits during the rest of the year.

Induction of Flowering through Chemicals

Floral induction in pineapple by selective chemicals to obtain scheduled fruiting is now widely practised. Ethylene was found to be the active ingredient in the smoke of the greenhouse at Azore islands, that induced flowering (Rodriguez, 1932). Other chemicals such as acetylene, generated by calcium carbide (Kerns, 1935), ethylene applied as a gas

(Cooper and Roose, 1941) and sodium salt of naphthalene acetic acid (NAA) showed usefulness to induce flowering in pineapple (Clark and Kerns, 1942; Gowing, 1956). Betahydroxy-ethylhydrazine (BOH) in water sprays was also found effective in inducing flowering under certain conditions (Gowing and Leeper, 1955). Ethephon (2-chloro-ehylphosphonic acid) has also been found effective (Cooke and Randall, 1968; Py and Guyot, 1970; Wee and Ng, 1971). These have been widely used since the past 15-30 years with suitable modifications in respect of dosage, time and stage of application, depending upon the climate and local needs.

In areas where warm summers and frequent rains produce rapid plant growth, NAA and BOH have not been always effective on Smooth Cayenne (Py and Silvy, 1964; Py, 1963; Py and Barbier, 1966) or on Singapore Spanish (Wee and Ng, 1970). On the other hand, ethylene applied as a water spray has been successfully used in warm and wet tropics, where suitable equipment has been developed.

Acetylene-generating calcium carbide is also used extensively in many warm, rainy areas. Yet, it has frequently failed to induce flowering in a large proportion of plants in Smooth Cayenne (Py and Silvy, 1954; Py and Barbier, 1966; Py and Guyot, 1970), but occasionally it was partially effective on Singapore Spanish and Sarawak (Wee and Ng, 1968; 1970; 1971). Repeated day-time spraying of acetylene solution on Smooth Cayenne was found more effective than single application (Py and Silvy, 1954; Py and Barbier, 1966).

Meagre information is available on the time of application. Py and Barbier (1966) found a single application of BOH or calcium carbide either dry or wet at the centre of the Smooth Cayenne plants, and found it more effective at 4.00 a.m. than at 10.00 a.m. Aldrich and Nakasone (1975) reported 100% flowering by the application of calcium carbide (dry) as powder or with water at the core of the plants. The effective concentration varied between 0.5% and 2.0% and the best time of application was from 8.00 p.m. to 9.00 a.m.

At the Golden Circle Cannery in Autstralia several studies were made. Application of 2 rounds of sodium salt of α-naphthaleneacetic acid (Sodium NAA) at 10 ppm at the rate of 2 fluid ounces per plant or sucker in the heart of the plant effected good flowering. Second dose of sodium NAA was given 14–21 days after the first. Another study used granular carbide for spot gassing, followed by 10 ppm sodium NAA within a week (carbide plus sodium NAA). In the third, 2 rounds of ethylene were applied with specially equipped boom-sprayers. Some basic differences exist between the 3 types of forcing agents. Carbide plus sodium NAA treated plants tend to throw well-

shaped fruits with some slips. But this method is suitable only for small plantings or where only a limited number of plants are to be treated individually. Two rounds of sodium NAA method is the simplest but treated plants tend to throw slightly smaller fruits and fruits may be more tapered than normal. In addition, slip production is reduced (either a desirable or undesirable characteristic, depending upon whether slips are needed or not). Two rounds of ethylene method is suitable only to specially designed boom sprayers. Ethylene, for best results, must be applied in late afternoon or at dusk. Its advantages are well-shaped fruits, weighing slightly more than NAA forced fruits, and higher slip and sucker production. However, preliminary cannery studies showed no marked differences in recovery, which would favour one method over the another. Finally, the choice of the method is up to the individual growers.

In India, intensive efforts have been made since 1970 to select right chemicals, suitable concentration and time of application for flower induction in Kew pineapple. Application of NAA and NAA-based compounds like Planofix and Celemone has been reported to be very effective in inducing flowering (Das, 1964; Balakrishnan *et al.*, 1978b; Maity and Sambui, 1980). According to Burg and Burg (1966), flowering is a consequence of the stimulation of the ethylene biogenesis by about a week following auxin treatment. But disadvantages with NAA are

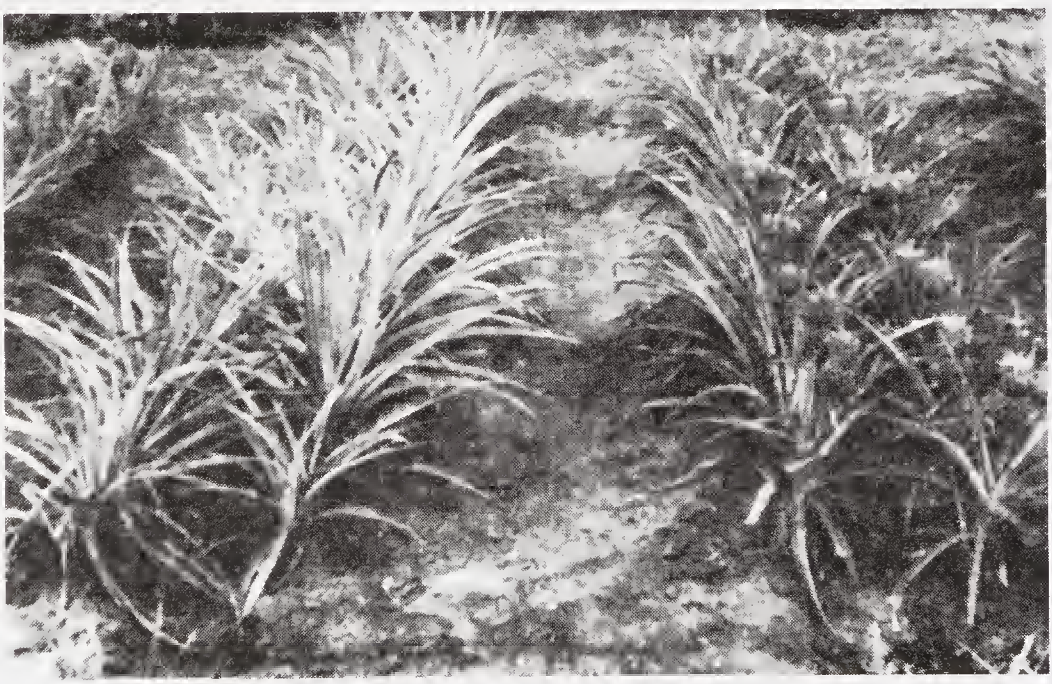

Fig. 15. Uniform flower induction with ethephon (right) and no flower induction in control (left).

delayed fruit maturity (Das, 1964) and inconsistent flower induction from season to season.

Calcium carbide had resulted in off-season flowering in June to the extent of 93% in Chethalli (Coorg). Small pellets of carbide at the rate of 1 g/plant were placed at the heart of the plant; acetylene was released when the product came in contact with water (Singh and Rameshwar, 1976). In Assam, 76% flowering was achieved with calcium carbide (Das *et al.,* 1965). Ethephon (usually under the trade name of Ethrel) was found to induce more uniform flowering as compared to NAA or NAD (naphthalene acetamide) (Randhawa *et al.,* 1970). The ethephon concentration at 100 ppm was most effective (Fig. 15). As treatment with 50 ml of 100 ppm Ethrel seemed to be costly, efforts were made at the Indian Institute of Horticultural Research, Bangalore, at Chethalli (Coorg) and at Thrissur, to lower concentrations of Ethrel. It was possible to induce more than 90% flowering with 25 ppm of ethephon in combination with 2% urea and 0.04% sodium carbonate (Dass *et al.,* 1975; Balakrishnan *et al.,* 1978 a). Urea helps in better absorption of any organic compound into the plant system and sodium carbonate increases release of ethylene by increasing pH of the solution.

Investigations carried out at the Pineapple Research Station at Mohitnagar in Jalpaiguri district of West Bengal have revealed that application of 50 ml solution per plant containing calcium carbide (20 g/litre) or Ethrel (0.25 ml/litre) causes flower induction.

Efficacy of growth regulators is influenced by the season. Trials were undertaken to find out suitable growth regulators for a particular season. Ethrel at 25 ppm along with 2% urea + 0.04% sodium carbonate was

Table 9. Influence of Ethrel and NAA on flower induction in different seasons on Kew pineapple

	Growth regulators	Flower induction (%) during			
		December-January	March-April	June-July	September-October
1.	Ethrel 25 ppm + 2% urea + 0.04% sodium carbonate	99.33	100.00	97.23	99.33
2.	Ethrel 10 ppm + 2% urea + 0.04% sodium carbonate	77.41	97.33	63.23	77.41
3.	NAA 10 ppm	98.23	50.66	88.66	98.23
4.	Control (water spray)	40.80	17.33	14.66	28.15

effective during all seasons. However, NAA was at a par during September to January. Still lower concentration of Ethrel, i.e. 10 ppm + 2.0 % urea + 0.04% sodium carbonate, can induce 97% flowering during dry months (March - May). At times or places where Ethrel is not available, NAA 10 ppm in combination with 2.0% urea can induce more than 90% flowering in Kew pineapple.

Based on the findings presented in Table 9, it would be advisable to use following growth regulators for different months for inducing flowering.

September-January	–	NAA 10 ppm (Planofix 1 ml/4.5 litres of water)
March - May	–	Ethrel 10 ppm (2.5 ml/100 litres of water) + 2% urea + 0.04% sodium carbonate
All months	-	Ethrel 25 ppm (6.25 ml/100 litres of water) + 2% urea + 0.04% sodium carbonate

Stage of Growth for Chemical Application

Once the growth regulators or chemicals are selected, it is also very important to know the stage of the plant when it could be induced to flower. Though, growth regulators or chemicals selected can induce flowering at any stage of the plant growth, forcing plant to produce flowers at an early stage, but this reduces fruit size. When plants of optimum size are forced to flower at the right stage, better fruit size is obtained, without any adverse effects on the ratoon crop. Hence, stage of .plant as denoted by the leaf number has been standardized. It was found that 35–39 active leaf stage (physiologically) was fit for treatment with 50 ml of 100 ppm Ethrel solution (Dass *et al.*, 1977). No beneficial effect was obtained with further increase in leaf number (Table 10). Optimum stage with regard to 'D' leaf was around 40–50 g.

Table 10. Effect of ethephon at different leaf number levels on yield attributes of Kew pineapple

No. of leaves	Average fruit wt	No. of suckers/plant	No. of slips/plant
25-29	1.077	0.53	0.58
30-34	1.413	0.77	1.47
35-39	1.789	1.24	3.41
40-44	1.780	1.09	3.57
45-49	1.914	1.11	3.64

For chemical induction of flowering in pineapple, the Golden Circle Cannery suggests that if average weight of 10 randomly collected 'D' leaves is 900 g, the plants are mature enough to produce good marketable fruits.

Method of Application

After preparing solution of required chemical or growth regulator, 50 ml of the solution should be poured into the heart of the plant. Efficacy of flower-inducing compound is reduced during rainy reason. Therefore, care should be taken that no rains are received for 24–36 hours after the application of the chemical. Otherwise application has to be repeated. Plants start flowering in 45–50 days after application.

Year-round Availability of Fruits

There is a possibility of spreading fruit harvest almost throughout the year by (i) taking up pineapple planting at regular intervals all round the year, (ii) using suckers and slips of different sizes and crowns as planting material and (iii) by the application of flower-inducing chemicals.

Studies carried out at the Pineapple Research Station of the Bidhan Chandra Krishi Vishwa Vidyalaya at Mohitnagar have revealed that in order to harvest fruits throughout the year, slips or suckers of pineapple should be planted from July to December, followed by application of Ethrel (0.25 ml/1) or calcium carbide (20 g/l), between 335 and 365 days after planting. The flower-inducing chemical should be applied to the heart of the plant between 7 p.m. and 8 p.m. in the evening and only when plants have at least 45–50 leaves. Application of chemicals at an interval of 7 days from April to November can ensure a steady harvest of fruits throughout the year (Aich, 1981).

Advantages of Flower Induction

1. Reduction in the cost of cultivation by restricting vegetative phase
2. Uniformity in harvest
3. Assured yield
4. Premium price to the grower through off-season crop
5. Regular supply of the fruits throughout the year to the canneries.

IMPROVING FRUIT SIZE AND QUALITY

Application of NAA at a concentration of 300 ppm to the developing fruits 2 months after flowering resulted in maximum fruit size (Kwong

and Chiu, 1968). Poignant (1969) recorded an increase in fruit weight, yield and a reduction in total sugars by the application of sodium salt of NAA at 110, 155 and 200 ppm on the developing fruits at 12-16 weeks after emergence of inflorescence. The best time for spraying developing pineapple-fruits of Singapore Spanish with Planofix was 6 weeks after the emergence of inflorescence (Wee, 1971). It resulted in increased fruit weight, diameter and acidity and delayed fruit maturity. Experiments conducted at the Indian Institute of Horticultural Research, Bangalore, have shown that application of NAA at 200-300 ppm concentration 2-3 months after fruit set increases fruit size by 15-20% (IIHR, Bangalore 1977). Similarly, 400 ppm of NAA applied 2 months before harvest also improved fruit weight (cited by Chadha, 1977). Roy (1981) suggested use of NAA (300 mg/litre) 45 days after flower emergence. The treated fruits showed an increase in weight and size and a reduction in total soluble solids and soluble sugar contents. Further, application of Ethrel (0.50 ml/l) on the NAA treated fruits at 120 days after flower emergence was found to improve fruit quality.

Ripening

Ethrel 2,000 ppm was found to induce uniform ripening which resulted in a single harvest of crop (cited by Chadha, 1977). Pre-harvest treatment of mature green pineapple variety Perola with Ethrel at 500-2,000 ppm resulted in development of uniform yellow colour in 8 days (Chunha *et al.*, 1980). Crochon *et al.* (1981) observed that application of Ethrel at 3 litres/ha, when fruits begin to colour, enabled complete harvesting 4 days later. While application of Ethrel 9 days before the harvest date at 5 litres/ha made fruits ready for harvest 5 days after treatment. Though, the appearance of the treated fruits was good, they were acidic and lacked flavour. On the other hand, 400 ppm of NAA solution applied to fruits one month before harvest, could delay maturity by 15 days (cited by Chadha, 1977). Das (1964) also experienced delayed fruit ripening with NAA treatments. These results may profitably be made use of depending upon the situation, either to postpone or to hasten harvest.

13

Harvesting and Yield

HARVESTING

PINEAPPLE flowers 10-12 months after planting and attains harvesting stage 15-18 months after planting, depending upon the variety, time of planting, type and size of plant-material used and prevailing temperature during the fruit development. Irregular flowering results in harvesting spread over a longer period. In nature, pineapple comes to harvest during May to August. This results in prolonged vegetative phase; and supplies of fruits to factories cannot be properly regulated. Besides, fruits which mature in winter are acidic. There is also a scope of altering fruit size and maturation with the use of chemicals or plant regulators.

The stage of harvesting in pineapple is very important. If it is harvested at immature stage, it does not develop its full sugar content and flavour. If left until it is too ripe it loses its flavour and appearance, resulting in flat-and-insipid fruits. Hence, it is very essential to harvest fruits at an ideal stage of ripening. In Kew pineapple, Mookerji *et al.* (1969) found harvesting at 137 days after flowering as optimum in Thrissur (Kerala) for canning purposes. Studies on optimal harvest maturity of Kew pineapple in North Bengal have shown that fruits harvested between 115 and 130 days after flowering were better suited for canning (cited by Bose, 1985). In Bangalore, Chadha *et al.* (1972) noticed increase in fruit size up to 165 days after flowering. Biswas *et al.* (1979) also observed close correlation between fruit weight and days taken from flowering to harvest. The disparity in these observations may be because of high temperatures prevailing at Thrissur and North Bengal, as a result of which required summation of heat units is achieved in a shorter period than at Bangalore.

The most commonly followed index of harvesting Kew pineapple is yellowing of the basal 1/2 to 2/3rd portion of the fruit for local market, and yellowing of basal 1/3 to 1/2 portion for distant market and canning factories. Harvesting should be done with a sharp knife, severing fruit-stalk with a clean cut, retaining 3-5 cm long stalk attached to fruit. Crowns are not detached. Though, maturity or harvesting standards are prescribed, experience is necessary to decide the exact degree of ripeness for harvest.

Fruits are packed in baskets woven with bamboo strips. For local

Table 11. Yield of Kew pineapple obtained at different places under varying plant densities

IIHR, Bangalore			Kerala Agricultural University Thrissur, Kerala			Bidhan Chandra Krishi Vishwa Vidyalaya, Mohitnagar, West Bengal		
Plant density/ha	Spacing (cm)	Yield/ha without crown (tonnes)	Plant density/ha	Spacing (cm)	Yield/ha without crown (tonnes)	Plant density/ha	Spacing (cm)	Yield/ha without crown (tonnes)
25,951	37.5 × 75 × 135	46.6	49,382	30 × 60 × 75	50.5	27,777	45 × 40 × 120	53.5
35,864	30 × 60 × 120	69.1	53,333	25 × 60 × 90	71.8	35,714	35 × 40 × 120	61.7
43,036	30 × 60 × 90	71.2				50,378	25 × 40 × 120	63.7
47,849	30 × 60 × 75	86.7	59,259	25× 60 × 75	81.5	57,971	30 × 40 × 75	65.2
			63,492	30 × 45 × 60	74.4			
53,796	30 × 60 × 60	85.9	66,666	25× 45 × 75	76.0	59,259	25 × 45 × 90	81.5
57,383	22.5 × 60 × 90	86.0	76,190	25 × 45 × 60	93.8	64,000	25 × 35 × 90	94.5
61,480	30 × 45 × 60	95.4	100,000	25 × 40 × 60	110.2	72,727	25 × 35 × 75	106.9
63,758	22.5 × 60 × 75	105.8						

markets, they are arranged in baskets lined with paddy-straw to stand on their stumps. The second layer of fruits is arranged on the crowns of the first layer of fruits. Each basket weighs 20-25 kg. For distant markets, fruits are wrapped individually with paddy straw and then packed.

RATOONING

The common practice is to renew plantation once in 4–5 years. The practice of continuing plantation for 20-30 years is seen in hill-side planting of Assam (Chadha, 1977). Experiments conducted at the Indian Institute of Horticultural Research, Bangalore, on ratooning in the high-density (55,500 plants/ha) plantings have revealed that the average fruit weight in the first and second ratoons was 88% and 79% of the plant-crop; and the plant stand also reduced, leading to reduction of fruit yield by 49.3% and 46.2% in the first and second ratoon crops (Chadha *et al.*, 1977). Prolonged ratooning would also result in reduction of flowering plants, consumer appeal of the fruit and size, and the number of fruits suitable for canning, but increase fasciated fruits. It was not possible to prevent reduction of fruit yield in ratoon crops by increasing irrigation or by higher doses of nitrogenous fertilizers (Rao *et al.*, 1977).

YIELD

Yield of pineapple varies with variety, agroclimate, agrotechniques followed, the type of planting material used and the planting density. Rao (1946) estimated pineapple yield at 6 tonnes/ha in India. The yields in Assam were 22 tonnes/ha (Chowdhury, 1947); but Bhattacharya and Sarma (1949) had put this figure at 12-15 tonnes/ha. The average yield in south India, irrespective of the variety, was 14 tonnes/ha and with Kew variety it was 25 tonnes/ha (Naik, 1963). According to the estimates of the Indian Institute of Foreign Trade, the average yield in India for pineapple is 10-15 tonnes/ha. It was consistently demonstrated at the Indian Institute of Horticultural Research and other institutes engaged in pineapple research in India that with the adoption of high-density planting and improved agrotechniques, high yields of pineapple, comparable to yields at Hawaii, the Philippines, Australia, Malaysia and Taiwan, can be obtained. The variations in yield under different plant populations at various places in India are presented in the Table 11.

Yield of pineapple could be forecasted based on the plant-growth characteristics. Number of leaves one year after planting and number of suckers in a plant could be used as indices of the size of the fruit with the following prediction equations (Chadha *et al.*, 1977)

1. Fruit weight in kg = 1,3987 + (0.0028 × No. of leaves)
2. Fruit weight in kg = 1,238 + (0.2520 × No. of suckers)

14

Economics of Production

ACCORDING to the estimates of the Indian Institute of Foreign Trade, the cost of production of one tonne of pineapple prior to 1968 was Rs 200 in India compared to Rs 110 and Rs 95 in Ivory Coast and the Philippines. As a result, the quotation for fresh and canned pineapples in the world market by these countries was far lower compared to our country. The low cost of production can be attributed to very high yields obtained by the manipulation of planting densities without any marked reduction in individual fruit size and quality. This lent a basis for research aimed at increasing yields by reducing cost of production.

Investigations carried out at the Indian Institute of Horticultural Research, Bangalore, revealed that by following high-planting density (63, 758 plants/ha), undoubtedly cost of cultivation increased along with the increase in net returns. A net return of Rs 33,950 was obtained from 63,758 plants/ha, as compared to Rs 11,728 from 43,036 plants/ha. By following high-density planting and other improved agrotechniques, it is possible to reduce cost of production of a tonne of fresh pineapple to Rs 71.90. The growers get Rs 1.06 per every rupee of his investment

Table 12. Economics of Kew pineapple cultivation under different planting densities (cost in rupees per hectare)

Particulars	Planting densities (plants/ha)					
	43,036	47,849	53,796	57,383	61,480	63,788
1. Total cost of cultivation (Rs/ha)	23,262	24,961	26,623	27,623	30,531	31,976
2. Yield of marketable fruits (tonnes/ha)	39.6	59.7	51.8	61.0	61.7	79.3
3. Value of fruit @ Rs 500 per tonne	19,800	29,850	25,900	30,500	30,850	39,650
4. Value of suckers and slips (Rs)	15,190	21,352	16,776	19,296	23,762	26,276
5. Net returns (Rs/ha)	11,728	26,242	15,983	22,173	24,081	33,950
6. Cost of production of a tonne of pineapple (Rs)	203.85	60.44	191.46	136.51	109.71	71.88
7. Net returns per rupee of investment	0.50	1.05	0.60	0.80	0.79	1.06

(Table 12; Chadha *et al.*, 1975). As per the estimates of the Kerala Agricultural University, a highest cost : benefit ratio of 1 : 4.2 could be obtained by planting 53,000 or 59,000 plants/ha (AICFIP, 1978). From West Bengal, it is reported that the net profit per hectare from one plant-crop followed by 2 ratoon crops (for 4 years) with a plant density of 44,440/ha was Rs 97,322 (DOA, West Bengal, 1976).

The economic analysis of the data on pineapple cultivation collected from Dakshina Kannada District of Karnataka revealed that a capital investment of Rs 51,000–62,000 was required for rainfed and irrigated crops for a crop sequence of a main crop followed by 2 ratoon crops, duration of which was 4½ years. The returns realized on an average were around Rs 22,000/ha/year, totalling to Rs 99,000/ha from the entire crop sequence (Subrahmanyam, 1987), based on the average yield of 31 tonnes/ha.

15
Pests and Diseases

PINEAPPLE suffers considerably from infestations of pests and diseases; though a few pests and diseases have been observed on it.

PESTS

Mealy-bug

It is the most widely distributed and probably also one of the most damaging pest, particularly to Smooth Cayenne (Collins, 1960). Abraham (1953) reported *Pseudococcus brevipes* (*Dysmicoccus brevipes*), a subspecies of mealy bug, to be the serious pest in the Wynad area of Kerala. The cause of wilting of plants is believed to be due to toxic secretions introduced into the plant by mealy bugs. However, some of the experimental data by Carter (1952) suggest a virus instead of a toxin etiology for mealy-bug wilt. In recent years, Singh and Sastry (1974) from India have shown that wilting is due to the pineapple wilt virus, and mealy bug is the vector for the virus.

The rapid spread of this malady in the field is largely due to the feeding habit of bugs. Often before visual symptoms appear, mealy bugs leave infected plants and move on to nearby healthy ones. Symptoms first appear on roots; and these are seldom observed because of being underground. The roots cease to grow, eventually leading to collapse of tissues. The most predominant symptom is wilting of leaves, commencing from leaf tips. Reddish-yellow colour develops in the wilting areas.

Mealy bugs in pineapple fields are attended by ants of several species, which carry mealy bugs from plant to plant.

Control of wilt involves destruction or elimination of mealy bugs and ant populations. Application of Phorate granules at the rate of 1.75 kg a.i./ha at 100 days after planting controlled mealy bugs at the Indian Institute of Horticultural Research, Bangalore. Care should be taken not to apply this insecticide at the time of flowering and fruiting because of its systemic nature. Indirect control of mealy bugs can be achieved by treating soil either with 27.5 kg/ha of Chlordane or Heptachlor at 22.5 kg/ha to check attendant ants. In Puerto Rico, 2 natural parasites *Hambletonia pseudococcins* and *Anagrus cocciduorus* are thought to control mealy bugs to some extent.

The most resistant varieties and species of pineapple to mealy-bug wilt are Red Spanish, Singapore Spanish, Pernambuco, Queen, *Ananas*

ananassoides, A. bracteatus and *Pseudananas sagenarious*. Some of the hybrids between Cayenne and resistant varieties or species are highly resistant to wilt. Breeding work at the University of Puerto Rico with Smooth Cayenne and Red Spanish resulted in 2 hybrids. They are PR 1-56 and PR 1-67; the former is resistant to wilt and the latter is tolerant to mealy-bug wilt.

Insect pests sporadically appearing in eastern India are stem-borer (*Metamasius ritchiei*) and scale insects (*Diaspis bromeliae*).

Other minor pineapple pests reported from elsewhere are fruit and stem borers (*Thecla echion*), termites, pineapple bug (*Carpophilus hemipterus*) and pineapple mite or red mite (*Stigmacus floridanas*) and pineapple scale (*Diaspis bromeliae*). The insecticidal application to soil or sprays used to control mealy bugs keeps these pests under control.

Rats affect mature or ripe pineapple fruits. Baiting with zinc phosphide in the pineapple plantation gives a reasonable, though not perfect, control.

Nematodes

Reduction in crop yields, particularly in ratoon crops has been caused by root-knot nematodes of *Meloidogyne* genus. The other genera which cause root-lesions or penetrate partially into roots of pineapple are *Pratylenchus* and *Rotylenchus*. Initially when the nematode population is low, plants do not exhibit any symptoms. But later, with increase in population, plant growth is restricted and finally chlorosis appears on leaves.

Plant material infested with nematodes should be destroyed and only healthy plant material should be used for new plantings. The common method followed to control nematodes is soil fumigation with ethylene dibromide (EDB) at 100 kg/ha or EDB 15 at 250 to 350 litres/ha, 2-3 weeks before planting depending upon the severity of infestation. As fumigation is an expensive operation, new nematicides such as Phenampiphos (Nemacur), Carbofuran (Furadan, Curaterr) and Ethoprophos (Mocap) with systemic action have come into use. Plants soaked in 1,500 ppm Nemacur solution and treated with 0.2 g/plant every 2 months were found free from nematodes (cited by Samson, 1980).

DISEASES

Butt Rot/Leaf Rot/Base Rot/Fruit Rot

The fungus *Ceratostomella paradoxa* cause rotting in planting material, fruits, plant stems and leaves under high moisture and humidity (Collins, 1960). Base or Butt rot of planting material occurs when they are not

dried and packed with little aeration. Fungus also destroys older plants by entering through wounds caused in the collar region while weeding or other operations.

Leaf rot, base rot and fruit rot are caused by *Ceratostomella paradoxa* throughout the pineapple-growing area of Assam (Chowdhury, 1945). While leaf rot is found to cause minor damage, base rot and fruit rot kill 4-10% of plants and damage 3-15% of fruits. These diseases can be controlled by dipping plant material in 0.3% Dithane Z-78 or by spraying on leaves. Copper fungicides should not be used in pineapple as they cause leaf scorching.

Black-rot or Soft-rot

This occurs in ripe fruits mostly after harvest; if there is a delay of some days between harvest and utilization. The causal organism is same as butt rot. Sridhar (1975) reported occurrence of black-rot from south India. The fungus makes its entry through wounds caused during picking and packing. Infestation starts at the stalk-end of the fruit, resulting in small, circular, water-soaked spots that are very soft. Gradually, fruit rots and emits foul smell. Dipping of fruits for 5 min in Thiabendazole 1000 ppm or Benomyl 3000 ppm would minimize rotting. Avoiding injury to fruit during harvest and transit will prevent disease occurrence.

Heart Rot or Stem Rot and Root Rot

The disease is caused by *Phytophthora cinnamoni* and *Phytophthora parasitica*. Infection due to *P. cinnamoni* is limited to areas of high rainfall and cool temperatures, although fungus is often present in soils of warmer and low rainfall areas. On the other hand, *P. parasitica* causes heart rot in warmer and somewhat drier areas. This organism is commonly seen in India. Poor physical condition of the soil and inadequate drainage are responsible for spread of the disease. It is frequently associated with alkaline soils but is not limited to them only. In this, green leaves turn yellowish-green and tips turn brown. The central whorl of leaves when affected will come out with a gentle pull. Basal portion of the leaves shows signs of rotting and emits foul odour. Control measures include good drainage, proper selection of healthy planting material and prophylactic treatment of planting material with Dithane Z-78 (0.3%) or Foltaf (0.4%). Affected plantations can be sprayed with Dithane or Foltaf.

Leaf Spot

It occurs frequently in moist, warm, climate of eastern parts of India. Small water-soaked areas develop on leaves which gradually enlarge

having pale-yellow colour and affected portions dry gradually. This disease is also caused by *Phytophthora* spp. (cited by Bose, 1985). Control measures are similar to heart rot.

Yellow Spot

This disease affects both plants and fruits and is caused by a virus (tomato-spotted-wilt virus) which is transmitted through thrips from hosts such as *Emilia sanchifolia,* a well-known Compositae weed. This was first recognized in Hawaii where host plant is common around pineapple fields. Eradicating weed-hosts may help in checking spread of disease.

16

Plant and Fruit Abnormalities

IN addition to pests and diseases, some fruit and plant abnormalities are found to occur, which make plants less productive and fruits useless. The abnormalities and their probable causes are as follows.

Crown without Fruit

A rare case was noticed where peduncle elongated and produced a crown without producing inflorescence. The crown developed normally, but not the fruit. Two reasons are attributed to it: (1) lack of food reserves for developing fruit as the plant was small and (2) an imbalance in the growth hormones (George and Oomen, 1968).

Multiple Crowns

Ordinarily fruit bears a single crown but in some cases fruit bears more than one, even to the extent of 25. Consequently the top of the fruit will be flat and broad and fruit will be unfit for canning (Fig. 16). Such fruits taste insipid and are corky. It is supposed to be a heritable character, found mostly in Cayenne group (George and Oomen, 1968).

Fig. 16. Fruit with multiple crowns

Multiple crowns are more frequent with low planting densities (Linford and Mehrlich, 1934) and when floral initiation occurs during dry-and-sunny period (Py *et al.*, 1987). In the latter case, irrigation reduces number of fruits affected. Vigorous growth with abundant fertilizer or planting on virgin ground, encourages multiple crowns (Linford and Spiegelberg, 1933).

Fruit and Crown Fasciation

Fasciated fruits are deformed to such an extent that they are totally useless. In certain cases, proliferation is so extreme that fruit is highly flattened and twisted with innumerable crowns, as high as 173 on it, stretched over a length of 76 cm in a twisted plane (Fig. 17). Fruits and crowns fasciation is associated with high vigour of plants. Such plants take longer time to flower. High fertility of soil and warm weather, where conditions are highly congenial for vigorous vegetative growth, may favour fasciation (George and Oomen, 1968). Excessively high temperatures during floral differentiation and calcium or zinc deficiency are said to be some of the causes for fasciating inflorescence (Py *et al.*, 1987). The incidence of fasciation was found to increase with advancing ratoons (Chadha *et al.*, 1977). The fasciation is due to some kind of accident affecting normal control of growth sequence during ontogeny (Collins, 1960). In addition, prevalence of favourable climate for

Fig. 17. A fasciated fruit with a series of crowns

vegetative growth during flower differentiation is supposed to cause this abnormality.

Collar of Slips

The collar of slips is typified by the presence of a large number of slips arising from stem close to the base of the fruit, or even directly from the fruits itself. The excessive slip growth is at the expense of the fruit, resulting in small, tapered fruits, often with knobs at the base. High nitrogen fertilization (Ganapathy *et al.*, 1977; Gonzales Tejera and Gandia Diaz, 1976) and high rainfall along with relatively low temperature are supposed to be congenial for such an abnormality (Ganapathy *et al.*, 1977).

Variations from true collar of slips type such as 'Near collar' and 'Knobby fruit' also occur.

Long Tom

The 'Long tom' is distinguished by excessive length and small diameter of fruit, which is usually knobby at the base and matures late. Sucker development is slow and slips are numerous.

Dry Fruit and Bottle Neck

The dry fruit and bottle neck fruit types are very similar and may be derived from the same parent. In dry fruit type, fruit is small, flowers are absent and fruitlets do not develop. In bottle neck, lower fruitlets develop normally and upper ones do not develop and give the same appearance as dry fruits. Suckers are freely produced from both the types.

Sun-Scald

This results when plant leans or falls over to one side, thus exposing one side of the fruit to direct sunlight. The cells of the exposed surface get damaged. Later shell surface assumes a brownish to black colour and cracks may appear between fruitlets. In high-density planting, intensity of sun-scald is very much minimized. Under favourable climates where leaf growth is luxuriant, leaves can be tied around the fruits to protect them from sun-scald. The other method is to cover sun-exposed portion of the fruit with dry straw or grass or with any other locally available materials.

In addition to these abnormalities, branching of the peduncle and proliferation of leaves and fruits have also been observed.

17
Storage and Processing

STORAGE

ADEQUATE ventilation is required to ensure arrival of fruits in perfect condition at the retail outlet if the fruits are to be transported for a shorter distance. Care should be taken to prevent bruising during harvesting and packing, and finally fruits have to be adequately protected against fungal infection.

When fruits are to be transported for long distances or for a period of several days, refrigerated transport is required to slow down ripening process. In tropical areas, pineapples could be stored well for 20 days when refrigerated at 10–13°C, provided fruits used for storage are healthy and unbruised (Huet and Tisseau, 1959). Fruits harvested in initial stages of ripeness remained saleable for longer after storage at 45°F. The total shelf-life of mature green- and half-ripe fruits was longer than those of ripe fruits. Akamine and Goo (1971) opined that 8°C is the optimum temperature for Smooth Cayenne fruits harvested at a relatively advanced stage of ripeness. The level of atmospheric oxygen in transport container can be reduced to slow down respiration. By maintaining oxygen at 2% by controlled nitrogen enrichment, Akamine and Goo (1971) succeeded in prolonging life of the fruits from 1 to 3 days. The best storage is at 7.2°C and 80 or 90% RH. The fruits of Red Spanish cultivar so stored for 7 days remained marketable for 9 more days than when they were kept at 15.6° C and 75% RH (Cancel, 1974).

Within the cold storage area, humidity should be maintained nearing to saturation level and air should be replaced wherever possible. However, at lower temperatures with longer storage period, there is a marked increase in acidity. In Smooth Cayenne, there was a 35% increase in acidity in fruits stored at 8°C for 10 days (Tisseau *et al.*, 1981). Storage at a temperature of less than 7°C may lead to serious deterioration of tissues. When temperature was around 20°C, there was a marked drop in acidity over a few days with subsequent breaking down of tissues (Tisseau, 1982), starting from epidermal and subepidermal tissues.

Storage life of Kew pineapples at 70°F both in summer and winter was 12 days, but by coating fruits with wax emulsion, it increased to 16 days (Bose *et al.*, 1962), and by treating fruits with 500 ppm 2, 4, 5-T and then coating with wax emulsion and storing them at 70°F increased their

storage life to 30 days. Fruits could be retained in good marketable condition up to 41 days at the Bidhan Chandra Krishi Vishwa Vidyalaya with the treatment of fruits with NAA and GA_3 at 500 ppm and 100 ppm. The untreated ones stored well only for 12-15 days at room temperature. GA_3 delayed development of yellow colour and NAA enhanced it. In addition, NAA was effective in preventing storage rot. In another study, mature and ripe pineapples were stored for 4 weeks at 11-13°C and 8-9°C and 85-90% relative humidity. Experiments carried out at the Hisar Agricultural University, indicated possibility of extending storage life with Benlate treatment (cited by Bose, 1985).

PROCESSING

The bulk of the world production of pineapple is used by canning industry and the trade in fresh fruits is limited. It is estimated that nearly 97% of the world output is utilized by processing industry.

Among the canned fruits, pineapples are important next only to peaches. Production of canned pineapple products which escalated to a level of 880,000 tonnes in 1971 from a level of 720,000 tonnes during 1970, started declining till 1975 at 12.4% to reach a level oı 770,000 tonnes. Since then, year-to-year wide fluctuations were observed in pineapple processed products. Several steps have been taken by various countries to ensure that pineapple cultivation and processing are given systematic attention with an eye on export market.

Utilization of pineapple produced in our country does not follow world pattern. Though pineapple is an excellent material to be preserved in different forms; bulk of the pineapple produced in the country is consumed in fresh form, the proportion used for processing being less than 10%. This is in contrast to the principal producing countries, where over 95% of the pineapple is absorbed by the processing industry.

Range of Products

The product of prestige is the canned pineapple slices in syrup, which are almost universally used as dessert and are also used in preparation of variety of dishes. Broken slices are generally considered a by-product of slices. The main categories are half slices, broken slices and different types of segments – chunks, tidbits, cubes. Segments are mainly used in pastry-making and confectionery. The last product of canning process is juice, which can be sold in pure or concentrated form and is also used in manufacture of various beverages like jam, squash, syrup and fruit-nectar. Among all forms, canned slices and juice are in much demand in India, constituting roughly about 70% of the

production. Small fruits cannot be used for production of slices. Medium-sized fruits of Kew or Giant Kew are suitable for canning in the most popular A 2½ size cans. Kew pineapple with its length/breadth ratio of 1.5 and taper ratio of 0.96 at ripe stage is found ideal for canning (Chadha *et al.*, 1972).

Wastes, which come mainly from top and bottom ends of fruit and shell, represent around 35% of the total weight of the fruit at modern canneries and up to 50% at the less equipped canneries (Py *et al.*, 1987). It is becoming common to use these wastes to extract second grade juice for syrup that covers pineapple slices. True waste in modern canneries means residues left after pressing, and in a modern cannery residues represent only 3–8% of the total weight of the fruit.

Pineapple products turn over is maximum in India, next only to mango. Share of pineapple slices is nearly 56% and of juice and jam is 15 and 10%.

Packing of Products

Pack sizes adopted for pineapple products in India are as follows.

Pineapple slices. A 2½ can corresponding to 850 g is by far the most popular size for pineapple slices, accounting for nearly 79% of the quantity packed. Next comes No. 1 tall can (1 lb) for 8%. The balance is canned in bottles.

Pineapple juice. For juice also A 2½ can is the most popular size accounting for 50% of the total quantity packed. No. 1 tall can (1 lb) and 5½ oz cans represent 17% and 8% of the total. Canning is also done in 5 lb cans and bottles.

Pineapple jam. In case of pineapple jam, 1 lb bottles claim the largest share of 58%. The share of A 2½ and 1 lb cans is limited to 12 and 13%. Jam is also canned in 5 lb "dalda" can; it is 12% of the total.

Pineapple tidbits and pulp. These are often canned only in A 2½ size can.

Infrastructure Available

The available infrastructure for processing pineapples in India includes factories both in private and public sectors. In 1977, there were 16, 12 and 3 factories engaged in production of pineapple products in Kerala, Karnataka and Tamil Nadu. In north-eastern region (excluding West Bengal) in 1970 there were about 20 licensed fruit-processing factories, of which 11 belonged to cottage-industry category. Even other 9 were only small-scale units. The combined production of all these 20 units was 429 tonnes. In the north-eastern region, there is a great scope for expansion of the processing industry not only to meet existing

production but also to meet demand of the expanding pineapple industry. In 1988, a processing unit to make pineapple concentrate with a crushing capacity of 2 tonnes/hour was set up by the NERAMAC (North Eastern Regional Agricultural Marketing Corporation Ltd.,) at Nalkata near Agartala in Tripura. This unit helps to utilize available fruits for making concentrate and also in expanding area and production under pineapple in the north-eastern states.

Cost Structure of the Products

The production costs of any product determines its sale price. To have an idea of cost structure, several case studies have been made (Chadha, 1977). An analysis based on these studies is given briefly.

Raw Materials

Fruit. It was reported that on an average raw fruits gave 50% recovery by weight of the processed product. In cases, where rigid quality standards were kept, the quantum of raw materials used was still higher. Spoilage of fruit was reported at 5% of the total due to injuries in loading and unloading and harvesting either at pre-mature or over-ripe stage.

Sugar. Normally 1.75 - 2.00 quintals of sugar is required for production of one tonne of finished product. For export purposes, however, sugar is supplied on levy price.

Packing Charges

Cans. Cost of can also varies from Rs 1.30 to 1.96 per can. An allowance of damage at 2% is also allowed. In addition, can-reforming charges at the rate of Rs 7-8 per hundred are also paid.

Packing cases. Prices of packing cases also vary from year to year. These are reckoned as Rs 4-5 per case.

Labels. A single label costs at about Re 0.07. In addition, a wastage of about 1-2% is reckoned. Wages for pasting labels are on average Rs 8 per tonne.

Other charges. Cost of nailing, wiring, strapping, stencilling and miscellanceous as gumming is at about Re 0.90 per case.

Direct Expenses

Labour. On an average about 70-75 labourers (including males and females) are required in a shift of 2-3 tonnes of finished product. Labour wages, however, vary from place to place.

Variable overheads. This includes cost of electricity, steam, water, repair and maintenance and general office expenses on postage, stationery, printing, bank charges, taxes, totalling at Rs 6-7 per case.

Table 13. Comparative cost of production of a case of canned pineapple slices

Components	Philippines (Rs equivalent)	India	
		1	2
Fresh pineapple	6.52	12.76	32.00
Sugar	2.62	8.28	7.60
Cans	9.52	12.36	40.10
Labels and cartons	2.40	2.88	7.00
Utilities	0.60	1.23	0.90
Manufacturing labour	1.88	1.50	4.00
Plant and other overheads	5.40	6.74	14.10
Total	28.94	45.74	105.70

Note :(1) Survey of India's export potential of fresh and processed fruits and vegetables (1968)
(2) Position during 1975

Fixed expenses. There is a great variation in these charges from factory to factory. These include supervision, salaries, depreciation on building, plant and machinery. These also include interest on capital investment.

Transport charges. These vary depending on the distance of the factories from consuming centre in case of internal consumption and to nearest port in case of exports.

In 1968 when Indian Institute of Foreign Trade conducted survey on India's export potential, the cost of production of slices in India was much higher than in other countries like Philippines. Over the years due to all-round increases in prices, the cost of production has more than doubled (Table 13).

Processing Constraints

Major constraints in processing of pineapple are as follows.

(1) High cost of canning due to high cost of fruit, sugar, containers and overheads.
(2) Non-availability of fruits throughout the year.
(3) Lack of finance to utilize modern machinery.

Standardization of technology to bring down cost of production of fresh pineapple and its adoption by growers, assured market for the produce; and to produce pineapple throughout the year may go a long way in promoting pineapple industry in India.

18
Marketing and Export

MARKETING

MARKETING of fresh pineapple poses serious problem due to its highly perishable nature. Mature pineapple fruits cannot be stored for more than 4–5 days after harvesting. Therefore, it is necessary to take ample care to avoid any injury to fruits while transporting to major consumption centres. According to a study conducted by the Central Food Technological Research Institute, Mysore, losses due to spoilage in transit were as high as 48% while bringing fruits from Agartala to Calcutta. For the states of north-eastern region, Calcutta is the nearest major market. As a result of high cost on transportation, pineapples of north-eastern region become uncompetitive in Calcutta as against the supplies of Siliguri and Bidhan Nagar in West Bengal. Bidhan Nagar has emerged as a major assembling centre for pineapples grown in Siliguri sub-division. Besides Calcutta, supplies from here are directed to Kanpur, Lucknow, Delhi, Bombay, Jamshedpur and Ranchi. Generally, fruits from here are supplied to wholesalers on commission basis. Supplies from Goa are mainly directed to Bombay while from Kerala, Karnataka they are sent to Bombay, Madras and Bangalore.

Like many other fruits, majority of the cultivators sell their crop either through trade agents at village-level or commission agents at the market. Direct sale to processing industries was negligible; though pineapple is mostly used for processing purposes. This has resulted in long chain of intermediaries in the marketing process. As a consequence of this, cultivator's share in consumer's price was as low as 26% in Meghalaya and it was 48% in Kerala (Subrahmanyam, 1989), most of the profit was pocketed by intermediaries.

A cultivator in Karnataka has to spend around Rs 57 per quintal for self-marketing of pineapple crop, i.e. transporting produce to market and selling it. This high marketing cost explains as to why most of the cultivators prefer to sell to traders at the farm-level itself. The transport cost at 52% and commission charges at 42% have accounted for most of the marketing cost (Subrahmanyam, 1989). This shows that there is a need to decrease these elements of cost by providing cheap transport and by controlling activities of the commission agents. Steps like regulation of markets for pineapple and integration of production,

marketing and processing activities would go a long way in decreasing marketing cost and thereby encouraging cultivators for self-marketing. In recent times, grower's marketing co-operatives have come into service in Kerala, Karnataka, Orissa, Assam and Manipur to undertake marketing of fresh pineapple.

EXPORTS

Fresh Fruits

According to a study report of the Tropical Products Institute, London, during 1972 on the world market for fresh pineapples, the amount of fresh pineapples exported by growing countries is about 2% of the total world production. The remaining portion either goes for fresh consumption or processing.

The trend of export of fresh pineapples from India has increased considerably from hardly 16 tonnes in 1965-66 to 239,200 tonnes in 1995-96. During the last two years (1993-94 to 1995-96) itself, the quantity of pineapples exported has doubled. The value of fresh pineapple exported during 1995-96 was 2.92 million. Nepal, Saudi Arabia, Russia and Kuwait are some of the important countries importing pineapple from India. During 1995-96, Bhutan was the third largest pineapple importer from India, with a import of 50,000 tonnes.

Even though pineapple exports have been showing an upward trend, there is no consistency in our exports which is not a desirable feature, as continuous supply to a market is one of the foremost pre-requisites for successful exports (Table 14). Further though India is the fourth largest producer of pineapple, it exported only 0.14% of its total production. This is very low compared to other leading pineapple-exporting countries like Philippines with 16%, Ivory Coast with 26% and Mexico with 4% (Subrahmanyam, 1989). There is a vast scope for increasing exports of fresh fruits from India.

The major exporting countries of fresh pineapples are Philippines, Ivory Coast, Honduras, Mexico, Brazil, Taiwan, Malaysia and South Africa. Leading importing countries are France, Japan, USA, Italy, Germany, Spain, United Kingdom and Canada.

For the development of a sound export trade in fresh pineapple, the following major factors have been listed by the Indian Institute of Foreign Trade.

(1) Colour and aroma are two important quality characteristics, influencing purchase of fresh fruits. When fully ripe, fruit should have a clean, bright appearance and a deep golden yellow or bright orange colour.

Table 14. Export of fresh pineapple from India

(Quantity : in tonnes; Cost : in rupees)

Country	1993-94		1994-95		1995-96	
	Quantity	Price	Quantity	Price	Quantity	Price
Nepal	45,354	176,587	93,780	400,287	102,335	409,030
Saudi Arabia	31,821	496,905	2,280	23,654	150	3,000
Russia	15,300	269,742	–	–	76,000	1,587,778
Kuwait	11,676	137,849	–	–	635	16,063
Bahrain	5,912	82,192	–	–	–	–
Qatar	5,370	69,872	–	–	–	–
Oman	3,639	38,191	3,880	34,656	–	–
UAE	928	17,605	1,700	14,193	3,100	24,137
Maldive	205	4,174	1,300	9,850	–	–
France	4	30	–	–	2,600	347,662
Norway	–	–	9,000	315,045	–	–
UK	–	–	2,540	32,192	–	–
Bangladesh	–	–	1,760	20,135	4,400	6,588
Portugal	–	–	600	7,204	–	–
Bhutan	–	–	–	–	50,000	527,561
	120,209	1,293,147	116,840	857,216	239,220	2,921,819

Source : All-India Food Preservers Association

(2) Crown is taken as an indication of the quality of the fruit. The crown should be straight and well developed. The crown leaves should be turgid and green; leaves which turn brown on the edges or are limp indicate staleness and detract appearance of fruit.

(3) Care should be taken to ensure that fruit is harvested at the right stage. Harvested fruits when immature often have an aciduous taste and tend to develop a distinctly dull-yellow tinge.

(4) It is widely recommended that fruits should be harvested only in the coolest part of the day. It is preferable to leave fruits overnight in an open, dry, shady place, so that it can lose its field heat before packing. If fruit is harvested when moist, it should be thoroughly dried before packing, otherwise mildew may develop on the skin surface.

(5) Handling of pineapples after harvesting as well as packing, requires very careful attention. Even slightly excessive pressure of fingers during packing can cause bruising which does not show for 10 or 12 days.

(6) The fruits should be perfectly graded by size and appearance; pineapples in the range of 1–2.5 kg are popular in most markets.

(7) When transported under refrigeration, care must be taken against

chilling injuries. Exposure to temperatures below 45°F for 10 hours is reported under certain conditions to cause physiological disorder known as 'black heart'. Water logging or 'injection' is another defect which can develop as a result of excessive chilling.

(8) Supplies should be made available round the year; which could be possible through staggering of planting and flower induction.

(9) Exports should be built-up on the basis of volume and not profit margin. Excessively high margin of profit at various levels has been a factor responsible for relatively slow rise in world demand.

(10) Point-of-sale literature aimed at impressing upon the housewives the ease with which the fresh fruit can be prepared for eating is likely to be a useful aid to promote sales.

From the above, it can be concluded that India has so far not been successful to build-up exports of fresh pineapple as already envisaged. Concerted efforts in this direction are expected to give positive results.

Processed Products

There is a large demand of pineapple products within the country. Bulk of the total production is consumed in institutional sector namely defence, hotels and airlines. Household consumption of these products is very limited. There is scope for accelerating internal demand and need to undertake a detailed consumer study for understanding present and future pattern of consumption.

World trade in pineapple products is highly competitive with more than 10 countries competing to secure an increasing share of market. Several developing countries notably the Philippines, Taiwan, Malaysia, Kenya and Thailand have developed their pineapple industry during the last 20 years with an eye on the export markets. Most of them received technical and marketing assistance from developed countries. The export of processed pineapple from India is, however, quite small. The exports which were of the order of 44,858 tonnes valued at Rs 1.52 million during 1993-94, however rose to 311,210 and 320,736 tonnes valued at 15 million and 11 million respectively. Pineapple juice is the major product exported. Ukraine, Russia, Liberia, Brundi and Oman are important importing countries from India. During 1995-96, the USA also imported 18,360 tonnes of pineapple juice from India. Russia and Ukraine also imported 45,900 and 30,600 tonnes of pineapple squash from India during 1994-95. However, this product was not imported by any country during 1995-96. This again points to the fact that we have failed to maintain consistent exports of processed products also. Low-cost production base needs to be enlarged to augment exports to other countries.

Table 15. Export of processed pineapple from India

(Quantity : in tonnes; Value : in rupees)

Country	1993-94		1994-95		1995-96	
	Quantity	Value	Quantity	Value	Quantity	Value
			Pineapple Juice			
Ukraine	26,400	993,430	132,660	6,122,718	–	–
Russia	15,000	455,562	56,000	2,776,714	302,376	10,564,825
Tanzania	750	20,326	–	–	–	–
Liberia	–	–	17,010	262,293	–	–
Brundi	–	–	17,000	256,101	–	–
Oman	–	–	10,000	1,738,804	–	–
USA	–	–	–	–	18,360	400,960
Subtotal	42,150	1,469,318	232,670	11,156,630	320,736	10,965,785
			Pineapple Squash			
Netherlands	2,708	59,421	–	–	–	–
Russia	–	–	45,900	1,944,525	–	–
Ukraine	–	–	30,600	1,296,350	–	–
Subtotal	2,708	59,421	76,500	3,240,875	–	–
			Pineapple Prepared/Preserved			
Germany	–	–	2,040	589,436	–	–
Subtotal	–	–	2,040	589,436	–	–
Total	44,858	1,528,739	311,210	14,986,941	320,736	10,965,785

Source : All-India Food Preservers Association

Prospects and Constraints

India has not been able to make a dent in the world market despite suitable climate and soils, large area under pineapple and a good processing infrastructure available in the southern region of the country. There are several reasons why Indian exports have not caught up over the years compared to other countries.

(1) While the quality of Indian products has been meeting international standard, the price of these products has been high.

(2) The productivity of pineapple crop needs to be improved for increasing production commensurable with area increase to bring down the cost of production to make them competitive in the world market.

(3) As the cultivation of pineapple is highly capital intensive and is of semi-perennial nature, special credit facilities need to be provided to encourage its cultivation.

(4) Besides price competitiveness, the other constraints are lack of quality packaging, marking and labelling of Indian products.

(5) India at present lacks an image in the export market which is fully entrenched by several leading countries of the world. This is due to lack of publicity in the overseas markets.

(6) While steps needs to be taken to improve performance of Indian pineapple processing industry through Governmental support mainly in the form of reducing cost of packaging, the major thrust should be in the direction of evolving an efficient distribution network within and outside the country This calls for an integrated approach towards development of infrastructural facilities (transport and communications), development of primary markets, improvements in packing, storage and handling facilities and techniques and subsidization of fresh produce movements.

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Index

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